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Tropical Cyclone Activity in the North Atlantic Basin During the Weather Satellite Era, 1960–2014

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March 2016

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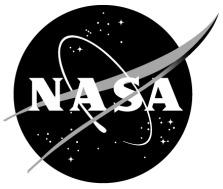
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LIST OF ACRONYMS, ABBREVIATIONS, AND DESIGNATORS

10-yma	10-year moving average
ACE	monthly accumulated cyclone energy
<ACE>	average accumulated cyclone energy
AMM	monthly Atlantic meridional mode
<AMM>	average Atlantic meridional mode
AMO	monthly Atlantic multidecadal oscillation
<AMO>	average Atlantic multidecadal oscillation
D–M	December to May
DOY	day of year
ENL	El Niño-like
ENSO	El Niño southern oscillation
FSD	first storm day
GLOTI	monthly global land-ocean temperature index
<GLOTI>	average global land-ocean temperature index
H	hurricane
HURDAT2	Hurricane Database 2
J–N	June to November
LIS	largest individual storm
LNL	La Niña-like
LOS	length of season
LP	lowest pressure
<LP>	average lowest pressure
LSD	last storm day
MH	major hurricane

LIST OF ACRONYMS, ABBREVIATIONS, AND DESIGNATORS (Continued)

N4/5	number of category 4 and 5 hurricanes
NH	number of hurricanes
NHD	number of hurricane days
NLAT	monthly north latitude
<NLAT>	average north latitude
NMH	number of major hurricanes
NMHD	number of major hurricane days
NOAA	National Oceanic and Atmospheric Administration
NSD	number of storm days
<NSD>	average number of storm days
NTC	number of tropical cyclones
NTCA	net tropical cyclone activity
NUSLFH	number of United States land-falling hurricanes
ONI	monthly oceanic Niño index
<ONI>	average oceanic Niño index
PDI	monthly power dissipation index
<PDI>	average power dissipation index
PWS	peak wind speed
<PWS>	average peak wind speed
QBO	monthly quasi-biennial oscillation
<QBO>	average quasi-biennial oscillation
TIROS	television infrared observational satellite
TP	Technical Publication
TS	tropical storm
U.S.	United States
WLONG	west longitude
<WLONG>	average west longitude

NOMENCLATURE

cl	confidence level
P	Probability
r	coefficient of linear correlation
r^2	coefficient of determination
sd	standard deviation
se	standard error of estimate
t	t-statistic
x	independent variable
y	dependent variable
Z	measure of statistical significance
ρ	nonparametric statistical test (Spearman)
τ_b	nonparametric statistical test (Kendall)

TECHNICAL PUBLICATION

TROPICAL CYCLONE ACTIVITY IN THE NORTH ATLANTIC BASIN DURING THE WEATHER SATELLITE ERA, 1960–2014

1. INTRODUCTION

This Technical Publication (TP) represents an extension of previous work concerning the tropical cyclone activity in the North Atlantic basin during the weather satellite era, 1960–2014, in particular, that of an article published in *The Journal of the Alabama Academy of Science*.[1–5] With the launch of the TIROS-1 polar-orbiting satellite in April 1960, a new era of global weather observation and monitoring began.[6–7] Prior to this, the conditions of the North Atlantic basin were determined only from ship reports, island reports, and long-range aircraft reconnaissance.[8–11] Consequently, storms that formed far from land, away from shipping lanes, and beyond the reach of aircraft possibly could be missed altogether, thereby leading to an underestimate of the true number of tropical cyclones forming in the basin. Additionally, new analysis techniques have come into use which sometimes has led to the inclusion of one or more storms at the end of a nominal hurricane season that otherwise would not have been included.

In this TP, examined are the yearly (or seasonal) and 10-year moving average (10-yma) values of the (1) first storm day (FSD), last storm day (LSD), and length of season (LOS); (2) frequencies of tropical cyclones (by class); (3) average peak 1-min sustained wind speed (<PWS>) and average lowest pressure (<LP>); (4) average genesis location in terms of north latitudinal (<NLAT>) and west longitudinal (<WLONG>) positions; (5) sum and average power dissipation index (<PDI>); (6) sum and average accumulated cyclone energy (<ACE>); (7) sum and average number of storm days (<NSD>); (8) sum of the number of hurricane days (NHD) and number of major hurricane days (NMHD); (9) net tropical cyclone activity index (NTCA); (10) largest individual storm (LIS) PWS, LP, PDI, ACE, NSD, NHD, NMHD; and (11) number of category 4 and 5 hurricanes (N4/5). Also examined are the December–May (D–M) and June–November (J–N) averages and 10-yma values of several climatic factors, including the (1) oceanic Niño index (<ONI>); (2) Atlantic multidecadal oscillation (<AMO>) index; (3) Atlantic meridional mode (<AMM>) index; (4) global land-ocean temperature index (<GLOTI>); and (5) quasi-biennial oscillation (<QBO>) index. Lastly, the associational aspects (using both linear and nonparametric statistical tests[12–14]) between selected tropical cyclone parameters and the climatic factors are examined based on their 10-yma trend values.

2. RESULTS

2.1 Tropical Cyclone Parameters

Tables 1 and 2, respectively, provide convenient listings of the yearly and 10-yma counts and values of the tropical cyclone parameters investigated in this study, as well as their parametric means and standard deviations (*sd*). The data were derived using the Hurricane Database 2 (HURDAT2) data listing found at <http://www.nhc.noaa.gov/data/hurdat/hurdat2-1851-2014-060415.txt>.

Table 1. Summary of yearly North Atlantic basin seasonal counts and parametric means.

Year	FSD	LSD	LOS	NTC	NH	NMH	NUSLFH	<PWS>	<LP>	Genesis Loc.		Sum PDI	<PDI>	ACE	<ACE>	NSD	<NSD>	NHD	NMHD	NTCA (%)
										<NLAT>	<WLONG>									
1960	175	263	89	7	4	2	2	82.1	971.7	21.4	71.2	93.5	13.4	88.0	12.6	29.50	4.21	18.25	9.75	92.9
1961	201	312	112	11	8	7	1	97.7	957.0	19.5	61.5	201.8	18.3	205.5	18.7	70.75	6.43	47.50	24.50	230.4
1962	239	295	57	5	3	1	–	75.0	974.8	22.7	57.4	25.2	5.0	35.5	7.1	22.25	4.45	10.75	0.50	40.9
1963#	214	302	89	9	7	2	1	81.1	978.1	19.7	60.1	95.1	10.6	117.8	13.1	52.00	5.78	37.25	7.00	116.2
1964&	159	313	155	12	6	6	4	82.1	968.2	21.9	62.7	156.2	13.0	170.0	14.2	71.25	5.94	43.00	14.75	183.9
1965#	165	291	127	6	4	1	1	76.7	973.3	22.8	63.5	72.7	12.1	84.4	14.1	39.50	6.58	27.25	7.50	85.9
1966	157	315	159	11	7	3	2	74.1	983.6	20.9	57.4	113.2	11.4	145.1	13.2	64.00	5.82	42.00	8.50	139.2
1967	242	304	63	8	6	1	1	79.4	975.8	20.1	56.3	101.5	12.7	121.9	15.2	58.00	7.25	36.25	5.50	100.8
1968	154	295	142	8	5	–	1	63.8	986.1	27.1	72.9	26.9	3.4	45.2	5.7	33.75	4.22	11.75	–	47.5
1969#	208	328	121	18	12	5	2	80.0	979.6	23.9	65.4	132.6	7.4	165.7	9.2	91.25	5.07	40.00	6.50	181.2
1970&	140	301	162	10	5	2	1	72.5	986.0	24.4	74.0	26.5	2.7	40.0	4.0	30.25	3.03	6.75	1.00	64.2
1971&	186	325	140	13	6	1	3	70.4	984.6	25.1	69.3	66.6	5.1	96.8	7.4	61.75	4.75	28.75	1.00	97.9
1972#	147	309	163	7	3	–	1	64.3	990.9	32.2	67.5	21.2	3.0	35.7	5.1	30.75	4.39	6.00	–	35.1
1973&	184	300	117	8	4	1	–	68.8	984.3	22.8	63.8	29.4	3.7	47.9	6.0	38.75	4.84	10.50	0.25	53.6
1974&	176	281	106	11	4	2	1	67.7	990.2	24.7	69.5	54.2	4.9	68.2	6.2	42.25	3.84	14.25	4.25	83.1
1975&	180	346	167	9	6	3	1	83.9	971.9	27.7	61.8	56.4	6.3	76.1	8.5	46.50	5.17	20.25	2.25	91.4
1976	144	302	159	10	6	2	1	70.0	981.8	25.0	65.2	62.0	6.2	84.0	8.4	49.75	4.98	25.25	1.00	86.2
1977#	242	291	50	6	5	1	1	79.2	982.2	28.1	77.4	20.9	3.5	25.4	4.2	14.75	2.46	6.75	1.00	44.7
1978*	212	305	94	11	5	2	–	68.6	986.5	23.5	66.1	46.6	4.2	61.5	5.6	40.50	3.68	13.50	3.50	82.3
1979	173	298	126	9	6	2	3	76.1	977.4	20.5	63.2	85.3	9.5	92.9	10.3	45.75	5.08	21.75	5.75	103.8
1980	215	332	118	11	9	2	1	83.2	976.1	23.8	54.1	141.6	12.9	149.3	13.6	62.25	5.66	38.25	7.25	130.3
1981	127	321	195	12	7	3	–	75.0	981.8	23.2	61.3	72.8	6.1	100.4	8.4	66.00	5.50	22.50	3.75	112.6
1982#	154	275	122	6	2	1	–	70.8	983.2	23.8	70.7	23.9	2.7	31.5	5.3	18.50	3.08	5.75	1.25	37.7
1983	227	273	47	4	3	1	1	72.5	985.5	28.6	75.9	10.8	2.7	17.4	4.4	13.75	3.44	3.50	0.25	30.5
1984	232	359	128	13	5	1	1	61.9	989.2	25.3	63.0	54.2	4.2	84.4	6.5	63.25	4.87	18.25	0.75	80.3
1985	197	327	131	11	7	3	6	78.2	977.4	25.2	71.6	67.5	6.1	88.0	8.0	51.25	4.66	21.25	4.00	105.8
1986#	157	325	169	6	4	–	2	67.5	992.8	24.3	69.3	24.9	4.2	35.8	6.0	23.25	3.88	10.50	–	36.8
1987#	221	286	66	7	3	1	1	59.3	992.3	19.2	56.8	19.0	2.7	34.4	4.9	37.25	5.32	4.00	0.50	44.9
1988&	220	329	110	12	5	3	1	72.9	976.2	21.6	64.6	93.9	7.8	103.1	8.6	46.75	3.90	21.25	9.00	117.0
1989	177	338	162	11	7	2	3	78.6	976.5	18.1	56.8	119.9	10.9	135.0	12.3	65.75	5.98	31.75	9.75	129.8
1990	205	293	89	14	8	1	–	65.4	987.1	19.6	52.1	62.6	4.5	96.8	6.9	72.50	5.18	26.75	1.00	100.3
1991#	185	306	122	8	4	2	1	68.1	981.6	26.6	64.0	25.0	3.1	35.7	4.5	24.25	3.03	8.25	1.25	57.7
1992	113	301	189	7	4	1	1	81.4	974.4	27.5	58.6	65.4	9.3	76.2	10.9	40.25	5.75	15.75	3.50	66.7

Table 1. Summary of yearly North Atlantic basin seasonal counts and parametric means (Continued).

Year	FSD	LSD	LOS	NTC	NH	NMH	NUSLFH	<PWS>	<LP>	Genesis Loc.		Sum PDI	<PDI>	ACE	<ACE>	NSD	<NSD>	NHD	NMHD	NTCA (%)
										<NLAT>	<WLONG>									
1993	170	264	95	8	4	1	1	60.6	989.9	20.4	63.1	25.6	3.2	38.4	4.8	29.25	3.66	9.75	0.75	51.5
1994#	183	324	142	7	3	–	–	65.0	989.6	18.3	62.1	19.2	2.7	32.1	4.6	28.75	4.11	7.25	–	35.3
1995	154	305	152	19	11	5	2	76.3	974.4	18.8	61.7	181.2	9.5	227.2	12.0	121.25	6.38	61.25	11.50	221.4
1996	171	331	161	13	9	6	2	80.0	972.8	16.2	62.2	142.6	11.0	166.2	12.8	79.00	6.08	45.00	13.00	192.2
1997#	152	290	139	8	3	1	1	55.6	990.8	27.1	69.8	29.1	3.9	40.8	5.1	29.75	3.72	9.50	2.25	53.7
1998&	210	335	126	14	10	3	3	83.2	972.7	19.2	57.5	157.9	11.3	181.7	13.0	87.75	6.27	48.50	9.25	167.9
1999&	163	325	163	12	8	5	3	91.3	964.6	17.5	64.1	159.2	13.3	176.4	14.7	78.50	6.54	40.25	14.00	180.4
2000&	217	303	87	15	8	3	–	70.0	981.7	21.0	62.3	89.2	5.9	119.2	7.9	71.25	4.75	32.75	5.00	133.5
2001	156	337	182	15	9	4	–	75.7	979.3	22.4	63.8	80.4	5.4	109.0	7.3	68.25	4.55	25.50	4.25	135.1
2002#	196	285	90	12	4	2	1	63.8	985.0	26.2	69.9	45.5	3.8	67.0	5.6	57.00	4.75	9.75	3.00	82.6
2003	110	344	235	16	7	3	2	70.6	981.8	22.0	64.7	165.1	10.3	176.4	11.0	92.50	5.78	32.50	16.75	178.6
2004#	214	337	124	15	9	6	6	82.3	971.2	20.0	57.8	217.7	13.8	226.7	15.1	93.00	6.15	45.50	22.25	231.4
2005	160	371	212	28	15	7	6	76.8	974.4	22.5	66.0	221.1	7.9	250.1	8.9	131.25	4.69	49.50	17.50	278.3
2006	162	275	114	10	5	2	–	68.5	984.7	21.9	56.6	55.1	5.5	78.5	7.9	63.75	6.38	21.25	2.00	88.7
2007&	129	346	218	15	6	2	1	65.0	986.1	21.9	65.1	73.1	4.9	73.8	4.9	38.25	2.55	12.25	6.00	98.8
2008	152	314	163	16	8	5	3	77.2	977.3	19.7	63.7	112.0	7.0	146.1	9.1	89.75	5.61	29.75	7.50	162.3
2009#	224	314	91	9	3	2	–	65.6	987.2	19.2	51.8	42.6	4.7	52.6	5.8	30.00	3.33	12.00	3.50	68.6
2010&	177	311	135	19	12	5	–	78.7	975.3	16.6	58.8	139.5	7.3	166.5	8.8	191.25	10.07	38.50	11.00	230.9
2011&	179	315	137	19	7	4	1	66.3	984.2	22.0	65.2	88.6	4.7	126.1	6.6	90.00	4.74	26.00	4.50	145.0
2012	140	303	164	19	10	2	1	66.6	981.8	21.9	58.4	85.9	4.5	136.3	7.2	102.75	5.41	24.50	0.25	120.9
2013	156	341	186	14	2	–	–	53.2	996.6	21.5	58.7	18.7	1.3	37.2	2.7	42.25	3.13	3.25	–	46.5
2014	182	300	119	8	6	2	1	76.3	977.3	19.4	67.2	58.2	7.3	73.0	9.1	37.75	4.72	19.50	3.75	83.9
sum				622	339	135	78													
mean	180	311	132	11.3	6.2	2.5	1.4	73.0	980.7	22.5	63.6	81.4	7.0	99.9	8.6	57.66	4.94	23.63	5.54	109.1
sd	33	23	42	4.5	2.8	1.8	1.5	8.5	7.6	3.3	5.7	55.3	3.8	58.7	3.7	32.29	1.33	14.49	5.79	60.2
median	177	305	128	11.0	6.0	2.0	1.0													97.9

* = ST1, an SS/TS that originated 01/19/1978 and ended on 01/22/1978 having PWS = 40 kt, LP =1,002, NSD = 3 days and a genesis location of 23.5º N., 64.6º W., is considered a statistical outlier; consequently, it is ignored in this analysis.

= ENL season; i.e., <ONI> (J–N) = 0.5 or more positive in value.

& = LNL season; i.e., <ONI> (J–N) = –0.5 or more negative in value.

Table 2. Summary of 10-yma North Atlantic basin seasonal counts and parametric means.

Year	FSD	LSD	LOS	NTC	NH	NMH	NUSLFH	<PWS>	<LP>	Genesis Loc.		Sum PDI	<PDI>	Sum ACE	<ACE>	Sum NSD	<NSD>	Sum NHD	Sum NMHD	NTCA (%)
										<NLAT>	<WLONG>									
1965	190	304	115	9.7	6.3	2.8	1.5	78.7	975.5	22.2	63.0	98.5	10.2	115.5	11.9	53.26	5.52	30.83	8.01	120.5
1966	187	306	120	9.9	6.2	2.5	1.5	76.9	977.6	22.6	63.5	88.4	9.0	107.7	10.9	52.85	5.37	29.31	6.40	112.4
1967	182	308	127	10.1	6.1	2.2	1.7	75.0	979.8	23.3	64.4	81.5	8.2	102.3	10.2	52.83	5.29	28.14	5.20	105.5
1968	176	308	134	10.2	6.0	2.1	1.7	73.8	980.9	24.0	65.1	78.0	7.8	98.8	9.8	52.59	5.24	26.56	4.84	102.1
1969	175	307	132	10.1	5.7	1.8	1.5	72.5	982.3	24.3	65.6	69.6	7.0	90.2	9.0	50.48	5.08	23.79	3.98	93.9
1970	177	308	132	10.2	5.7	1.7	1.3	72.1	983.4	24.6	65.9	63.7	6.4	84.7	8.3	49.38	4.91	22.00	3.19	89.1
1971	177	310	134	10.3	5.8	1.8	1.3	72.3	983.2	25.1	66.2	60.3	5.8	81.2	7.8	49.01	4.80	20.81	2.55	86.8
1972	176	308	133	10.1	5.7	1.7	1.2	72.1	983.4	25.7	67.6	53.7	5.1	73.3	7.0	46.14	4.51	18.50	1.95	81.3
1973	179	308	130	10.2	5.6	1.8	1.2	72.3	983.8	25.9	68.3	50.7	4.7	69.3	6.5	44.31	4.25	17.11	1.90	80.2
1974	180	307	128	9.9	5.3	1.8	1.2	72.3	983.7	25.6	67.9	49.3	4.8	66.5	6.5	42.38	4.22	16.29	2.04	78.1
1975	182	307	126	9.5	5.2	1.6	1.2	72.7	983.1	25.4	66.8	52.7	6.4	68.3	7.1	41.70	4.35	16.95	2.31	77.5
1976	183	309	127	9.5	5.5	1.7	1.1	73.5	982.5	25.2	65.4	58.7	6.3	74.0	7.6	43.51	4.52	18.21	2.76	81.6
1977	180	307	127	9.4	5.5	1.9	0.9	74.0	981.9	24.7	65.2	59.2	6.0	73.9	7.6	43.11	4.49	17.89	2.96	82.4
1978	183	304	122	9.1	5.4	1.9	0.9	74.5	981.6	24.6	65.9	58.4	6.0	72.2	7.1	41.25	4.36	17.53	3.03	81.4
1979	188	306	120	9.0	5.4	1.9	0.9	74.4	981.6	24.9	66.2	57.5	5.9	71.5	7.5	41.05	4.34	17.38	2.85	80.1
1980	191	309	119	9.2	5.5	1.8	1.2	73.8	981.8	24.8	66.4	58.0	5.8	72.9	7.5	42.34	4.37	17.63	2.76	80.7
1981	193	309	118	9.1	5.4	1.7	1.5	73.4	982.7	24.7	67.1	56.7	5.7	71.1	7.4	41.25	4.29	16.94	2.80	79.0
1982	193	310	119	9.0	5.2	1.6	1.5	72.3	983.7	24.2	66.2	54.8	5.6	69.1	7.3	41.05	4.37	16.06	2.73	76.5
1983	192	311	120	9.1	5.1	1.7	1.6	71.5	983.7	23.6	65.1	57.0	5.7	71.6	7.5	42.49	4.53	16.31	2.98	78.2
1984	193	315	123	9.2	5.2	1.7	1.6	71.9	983.1	23.4	64.7	61.1	6.0	75.8	7.7	42.85	4.58	17.20	3.45	81.3
1985	192	315	123	9.5	5.2	1.7	1.6	71.1	983.7	23.1	64.3	58.9	5.6	75.3	7.5	45.31	4.61	17.13	3.34	81.1
1986	195	312	118	9.4	5.0	1.6	1.6	69.9	984.2	23.1	64.3	52.6	5.0	69.4	6.9	43.74	4.46	15.84	2.90	76.8
1987	195	312	118	9.3	4.9	1.5	1.7	70.1	983.7	23.4	63.9	52.2	5.2	68.4	7.0	42.74	4.47	15.63	2.89	75.5
1988	191	313	124	9.5	5.1	1.5	1.7	70.0	983.5	23.2	62.6	55.1	5.6	71.7	7.3	44.60	4.61	16.44	3.03	78.0
1989	185	311	127	9.4	5.0	1.5	1.7	69.5	983.8	22.4	61.9	54.1	5.5	70.2	7.2	43.65	4.59	16.20	3.01	76.8
1990	181	308	128	9.5	5.1	1.5	1.4	69.6	983.6	21.8	61.4	58.0	5.6	74.5	7.4	45.43	4.63	17.65	3.35	80.4
1991	179	307	129	10.3	5.6	1.9	1.2	70.1	982.5	21.0	60.6	69.6	6.1	88.0	7.9	51.71	4.83	21.38	4.38	93.9
1992	176	308	132	10.7	5.8	2.2	1.2	70.6	981.4	21.0	60.9	75.9	6.5	94.8	8.2	54.13	4.86	23.38	5.11	102.1
1993	173	308	137	10.8	6.1	2.2	1.3	70.9	981.2	21.3	61.1	79.7	6.8	99.1	8.5	55.80	4.90	25.01	5.21	105.1
1994	171	308	138	11.0	6.4	2.4	1.4	72.1	980.4	21.2	61.2	84.8	7.1	105.1	8.8	58.49	5.04	26.80	5.44	110.2
1995	171	308	138	11.1	6.4	2.6	1.4	72.9	979.5	21.2	62.0	88.1	7.3	108.3	9.0	59.06	5.05	27.53	5.85	114.4
1996	170	310	141	11.5	6.7	2.8	1.4	73.5	979.1	21.1	62.5	92.2	7.4	113.1	9.2	61.20	5.11	28.69	6.20	119.9
1997	173	311	139	12.1	6.9	3.0	1.3	73.0	979.6	20.8	63.1	94.0	7.3	116.3	9.0	64.24	5.13	29.25	6.33	124.6

Table 2. Summary of 10-yma North Atlantic basin seasonal counts and parametric means (Continued).

Year	FSD	LSD	LOS	NTC	NH	NMH	NUSLFH	<PWS>	<LP>	Genesis Loc.		Sum PDI	<PDI>	Sum ACE	<ACE>	Sum NSD	<NSD>	Sum NHD	Sum NMHD	NTCA (%)
										<NLAT>	<WLONG>									
1998	174	314	141	12.7	7.1	3.1	1.4	72.7	979.7	20.8	63.7	100.0	7.4	122.7	9.1	68.21	5.19	30.09	7.10	131.7
1999	173	319	147	13.5	7.5	3.5	1.7	74.0	978.4	21.0	63.6	116.9	8.3	139.3	9.0	74.61	5.40	33.14	9.01	147.9
2000	175	323	149	14.4	8.0	3.9	2.2	74.9	977.4	21.2	63.6	128.8	8.7	150.2	10.3	78.33	5.41	34.46	10.43	160.5
2001	174	323	150	14.7	8.0	3.8	2.3	74.4	978.0	21.7	63.5	126.8	8.4	147.0	9.9	78.06	5.34	32.69	10.18	158.2
2002	173	323	151	14.9	8.0	3.7	2.2	74.3	978.4	21.7	63.0	124.2	8.2	144.2	9.6	77.73	5.30	31.64	9.81	155.3
2003	169	325	157	15.3	8.0	3.8	2.2	74.4	978.4	21.5	63.1	124.1	8.0	144.1	9.4	78.25	5.21	30.84	9.91	157.3
2004	169	323	155	15.3	7.7	3.8	2.1	72.8	979.7	21.6	62.8	116.0	7.4	136.1	8.8	75.93	5.01	28.49	9.30	151.4
2005	170	323	154	15.3	7.6	3.7	1.9	72.0	980.6	21.5	62.0	112.7	7.0	132.3	8.4	79.50	5.12	27.36	9.08	150.7
2006	169	322	154	15.7	7.7	3.8	2.0	72.0	980.5	21.2	61.9	115.6	7.0	135.5	8.4	86.59	5.40	27.68	9.39	156.0
2007	168	322	156	16.3	7.9	3.8	2.0	71.6	980.6	21.0	61.4	118.1	7.0	139.8	8.5	89.96	5.44	28.44	9.26	158.4
2008	167	323	157	16.5	8.0	3.7	1.9	70.9	981.1	20.7	60.5	112.8	6.6	136.4	8.1	89.74	5.34	27.71	8.29	153.7
2009	168	321	154	16.1	7.6	3.3	1.6	69.7	982.2	20.7	60.7	97.5	5.8	121.7	7.4	84.46	5.13	24.95	6.53	139.8
mean	180	312	134	11.3	6.2	2.4	1.5	72.6	981.3	22.8	63.9	79.5	6.6	98.1	8.3	56.56	4.87	23.20	5.20	106.9
sd	9	6	13	2.5	1.1	0.9	0.4	1.9	2.2	1.7	2.1	26.0	1.2	28.1	1.2	15.75	0.40	6.02	2.74	30.6
median	177	310	132	10.2	5.8	1.9	1.5	72.3	981.6	22.6	63.6	69.6	6.4	90.2	8.1	51.71	4.90	23.38	4.38	93.9

Figure 1 shows the (a) FSD, (b) LSD, and (c) LOS for the interval 1960–2014. The thin jagged lines are the annual parametric values and the thick smoothed lines are the 10-yma values. Based on the 10-yma values, one notices a downward trend in FSD, an upward trend in LSD, and an upward trend (or lengthening) in LOS. Hence, the FSD for a yearly hurricane season (conventionally, the interval spanning June 1–November 30) appears to be trending sooner, the LSD later, and the LOS longer than their respective long-term means, which are day of year (DOY) 180, DOY 311, and 132 days, respectively. The FSD for a hurricane season is simply defined as the day when the 1-min sustained wind speed of the first tropical cyclone of the hurricane season attains tropical storm wind speed (34 kt) and the tropical cyclone is not described as being 'extratropical' in nature. Similarly, the LSD is the last day when the last tropical cyclone of the season has a 1-min sustained wind speed of tropical storm strength and the tropical cyclone is again not described as being extratropical. The LOS then is merely the inclusive difference between LSD and FSD. (In figure 1(a), the occurrence of the FSD for the 2015 hurricane season is noted by the placement of Ana on the chart, which formed on May 8, 2015, or DOY = 128. The dashed lines show the effects of including the FSD for the 2015 hurricane season on the annual and 10-yma lines.)

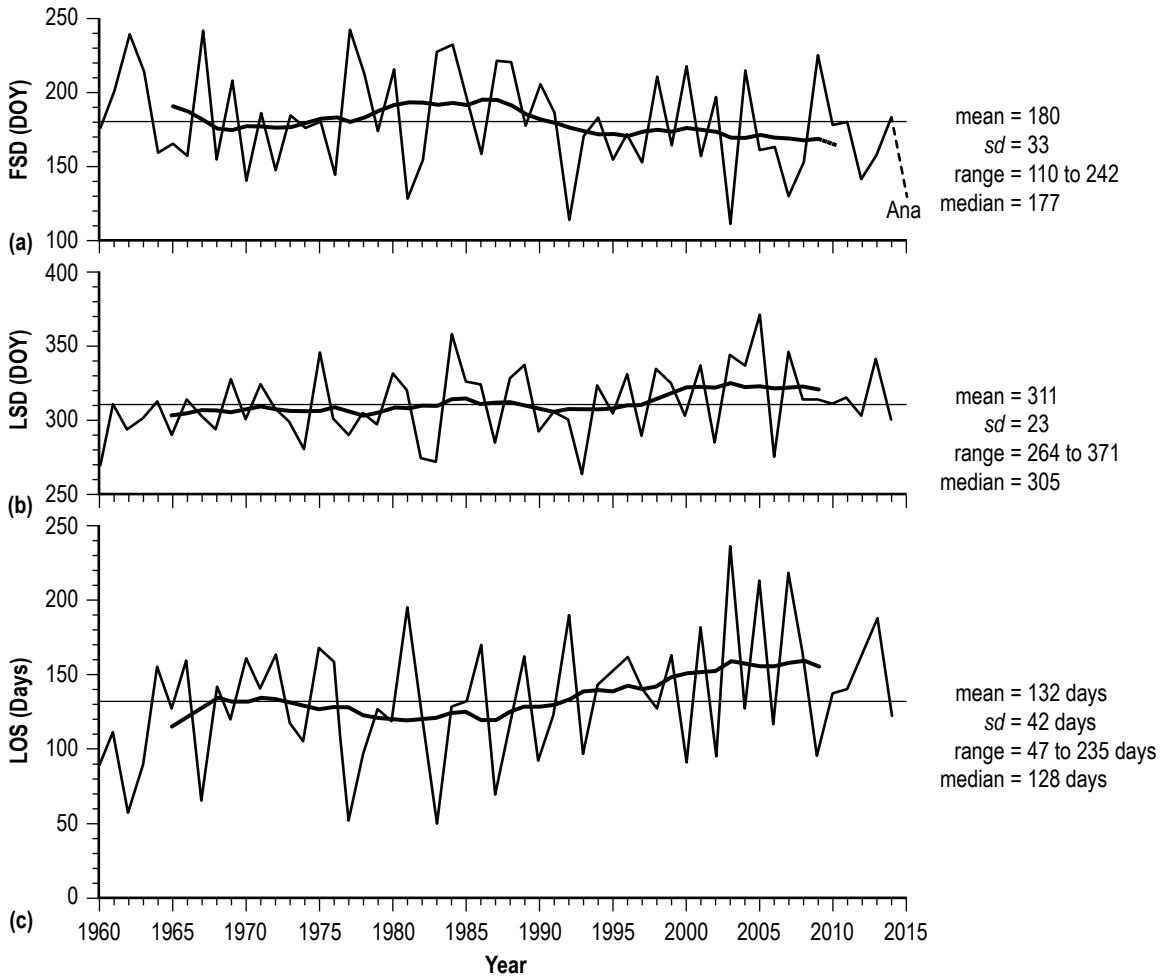


Figure 1. Annual and 10-yma variation of (a) FSD, (b) LSD, and (c) LOS.

Figure 2 displays the scatterplot of LOS versus FSD using annual values. Clearly, a very strong, inverse linear relationship is found to exist between LOS and FSD, with an early-occurring FSD highly suggestive of a longer-than-average LOS and a later-occurring FSD highly suggestive of a shorter-than-average LOS. In the chart, the thick diagonal line is the inferred linear regression line (y), the dashed lines represent the ±1 standard error of estimate (se) lines ($y \pm se$), and the thin vertical and horizontal lines are the parametric medians (used in the computation of the Fisher's exact test of the observed 2×2 contingency table). The inferred inverse linear regression is given as $y = 321.5 - 1.05x$, where y is the dependent variable LOS and x is the independent variable FSD. The inferred linear regression has a Pearson linear coefficient of correlation $r = -0.83$, a coefficient of determination $r^2 = 0.689$ (meaning that about 69% of the variance in LOS can be 'explained' by the variation in FSD alone), $se = 22.4$ days, and confidence level $cl \gg 99.9\%$. Based on the Fisher's exact test for the observed 2×2 contingency table (determined by the parametric medians), one finds the probability, P, of obtaining the observed result, or one more suggestive of a departure from independence (chance), to be $P = 0.08\%$. Based on the Spearman ρ and Kendall τ_b nonparametric statistical tests, one calculates them to be –0.795 and –0.619, respectively, having Z statistics equal to –5.842 and –6.673, respectively, with these values being highly indicative of a very strong inverse association between LOS and FSD. (In the figure, the ±1 se prediction estimate is given for the expected LOS for the 2015 hurricane season, computed to be about 187 ± 22 days, based on Ana's FSD = DOY 128.)

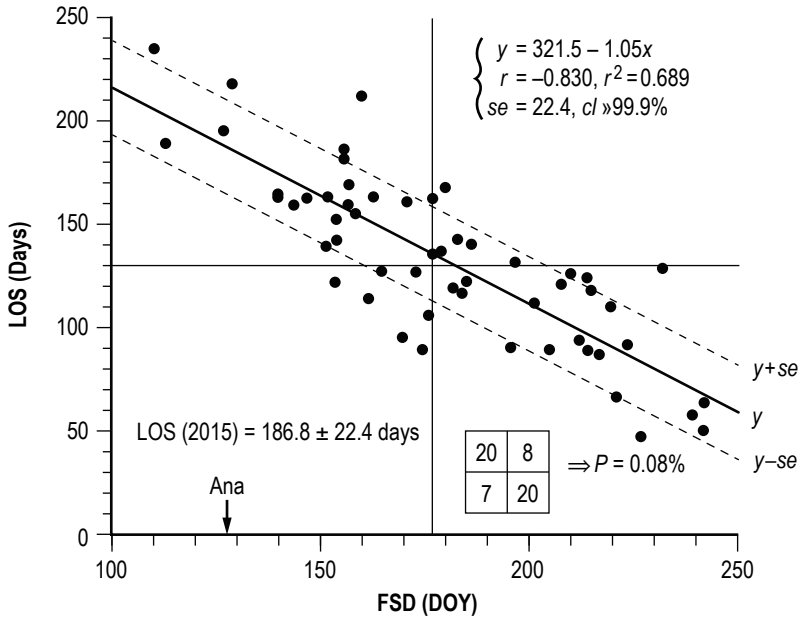


Figure 2. Scatterplot of LOS versus FSD using annual parametric values.

Figure 3 shows the annual and 10-yma variation of the (a) number of tropical cyclones (NTC), (b) number of hurricanes (NH), (c) number of major or 'intense' hurricanes (NMH, where a major hurricane is one having a Saffir-Simpson category of 3 or higher; i.e., having a peak 1-min sustained wind speed ≥96 kt), and (d) number of United States (U.S.) landfalling hurricanes (NUSLFH; i.e., the tropical cyclone struck the U.S. coastline as a hurricane, having a peak 1-min sustained wind

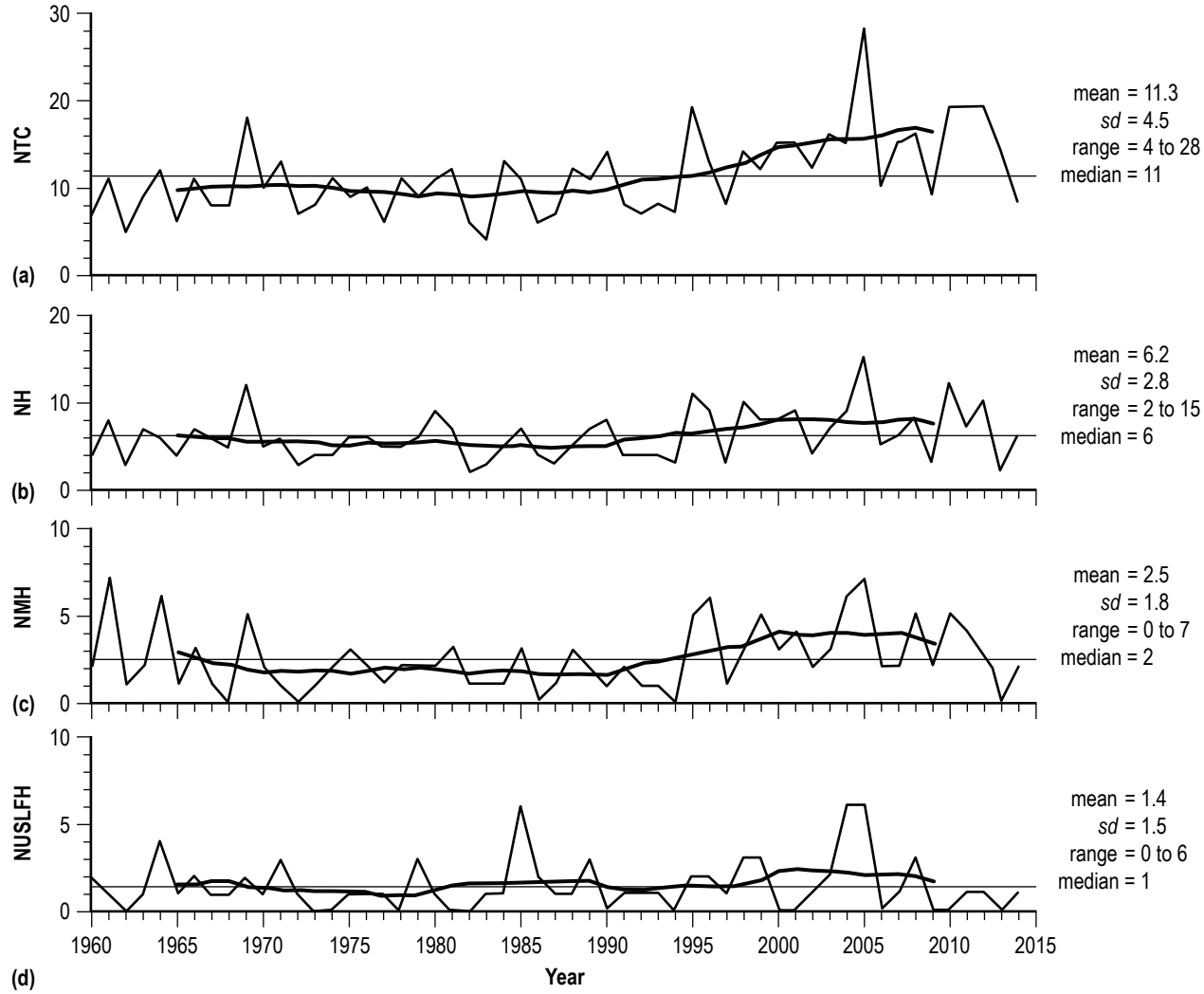


Figure 3. Annual and 10-yma variation of (a) NTC, (b) NH, (c) NMH, and (d) NUSLFH.

speed ≥64 kt). Thus, during the weather satellite era, tropical cyclones in the North Atlantic basin have averaged about 11 per year, with extremes of 4 (in 1983) and 28 (in 2005). About half (6.2) of the tropical cyclones are noted to have attained hurricane strength, with extremes being 2 (in 1982) and 15 (in 2005), and slightly less than half (2.4) of the hurricanes are noted to have attained major hurricane strength, with extremes of 0 (in 1968, 1972, 1986, 1994, and 2013) and 7 (in 1961 and 2005). On average, the NUSLFH has been about 1–2 per year, with extremes of 0 (in 1962, 1973, 1978, 1981, 1982, 1990, 1994, 2000, 2001, 2006, 2009, 2010, and 2013) and 6 (in 1985, 2004, and 2005).

Close inspection of figure 3, however, reveals that tropical cyclone activity in the North Atlantic basin has actually been considerably more robust of late (since the mid-1990s) than before. For the current ongoing subinterval 1995–2014, NTC has averaged about 15 storms per season as compared to about 9 per season for the earlier subinterval 1960–1994, with extremes during the current

subinterval being 8 (in 1997 and 2014) and 28 (in 2005). The t statistic for independent samples is computed to be $t = –5.38$, indicating that the difference in the means is highly statistically important. The same is true for NH, with the current subinterval averaging about 7–8 hurricanes per year and the earlier subinterval averaging about 5 hurricanes per year ($t = –3.23$) and also for NMH, with the current subinterval averaging about 3–4 major hurricanes per year and the earlier subinterval averaging only about 1–2 major hurricanes per year ($t = –3.12$). For NUSLFH, however, the difference in means is not statistically important ($t = –0.95$). Table 3 provides the results of t-testing of the difference between parametric means for the two subintervals 1960–1994 and 1995–2014 for all parameters included in this study, including several climatic factors, which will be discussed in the next subsection.

Table 3. Summary of t test for independent samples, 1960–1994 and 1995–2014.

	1960–1994		1995–2014		
	(*n* = 35)		(*n* = 20)		
Parameter	mean	*sd*	mean	*sd*	*t*
FSD	185.2	33.7	170.2	30.2	1.65
LSD	306.5	22.2	319.1	23.8	–1.97
LOS	122.4	38.7	149.9	42.1	–2.46
NTC	9.3	2.9	14.8	4.7	–5.38
NH	5.3	2.0	7.6	3.3	–3.23
NMH	1.9	1.6	3.4	1.9	–3.12
NUSLFH	1.3	1.3	1.7	1.8	–0.95
<PWS>	73.5	8.1	72.2	9.4	–0.54
<LP>	981.1	7.7	980.0	7.5	0.51
<NLAT>	23.4	3.3	20.9	2.8	2.85
<WLONG>	64.3	6.2	62.3	4.6	1.26
Sum PDI	66.1	45.7	108.1	61.4	–2.89
<PDI>	7.7	5.9	7.2	3.4	0.35
Sum ACE	81.9	47.2	131.5	64.6	–3.27
<ACE>	8.5	3.8	8.8	3.4	–0.29
Sum NSD	45.0	18.9	79.7	38.9	–4.46
<NSD>	4.7	1.1	5.3	1.6	–1.64
Sum NHD	20.4	12.8	29.4	15.9	–2.29
Sum NMHD	4.2	5.1	7.9	6.3	–2.37
NTCA	88.5	46.6	145.0	65.5	–3.72
SISPWS	123.1	23.0	126.5	19.4	–0.56
SISLP	940.5	21.3	930.5	20.9	1.69
SISPDI	27.6	19.3	36.2	20.5	–1.55
SISACE	28.1	15.9	35.9	15.2	–1.78
LISNSD	10.9	3.8	12.9	3.5	–1.93
LISNHD	7.6	3.9	8.4	2.8	–0.81
LISNMHD	2.7	2.7	4.0	2.7	–1.72
N(4/5)	1.0	1.1	2.0	1.5	–2.84

Table 3. Summary of *t* test for independent samples, 1960–1994 and 1995–2014 (Continued).

	1960–1994		1995–2014		
	(*n* = 35)		(*n* = 20)		
Parameter	mean	*sd*	mean	*sd*	*t*
<ONI>(D–M)	0.04	0.72	–0.17	0.76	1.02
<ONI>(J–N)	0.08	0.76	–0.05	0.76	0.61
<AMO>(D–M)	–0.126	0.157	0.103	0.102	–5.84
<AMO>(J–N)	–0.134	0.153	0.213	0.140	–8.34
<AMM>(D–M)	–0.66	2.41	1.08	1.79	–2.81
<AMM>(J–N)	–0.75	1.65	1.56	1.60	–5.00
<GLOTI>(D–M)	0.12	0.18	0.54	0.11	–9.45
<GLOTI>(J–N)	0.14	0.35	0.55	0.10	–5.10
<QBO>(D–M)	–1.69	8.99	–1.07	9.39	–0.24
<QBO>(J–N)	–4.96	11.12	–6.19	15.45	0.34

Figure 4 depicts the annual average and 10-yma variation of the genesis location of the tropical cyclones, in terms of (a) <NLAT> and (b) <WLONG>. The annual <NLAT> and <WLONG> are simply the averages of each storm's latitude and longitude components, as measured at storm onset during a single season (i.e., when the storm first becomes a tropical cyclone). As an example, in 1983 four tropical cyclones formed in the North Atlantic basin, including Alicia, Barry, Chantal, and Dean. These four storms had latitude-longitude values at onset of (27.2º N., 91.0º W.), (27.4º N., 76.3º W.), (31.6º N., 63.3º W.), and (28.0º N., 73.0º W.), respectively. The average latitude and longitude of these four storms then is (28.6º N., 75.9° W.), which are the values of <NLAT> and <WLONG> for the year 1983 tabulated in table 1 and plotted in figure 4.

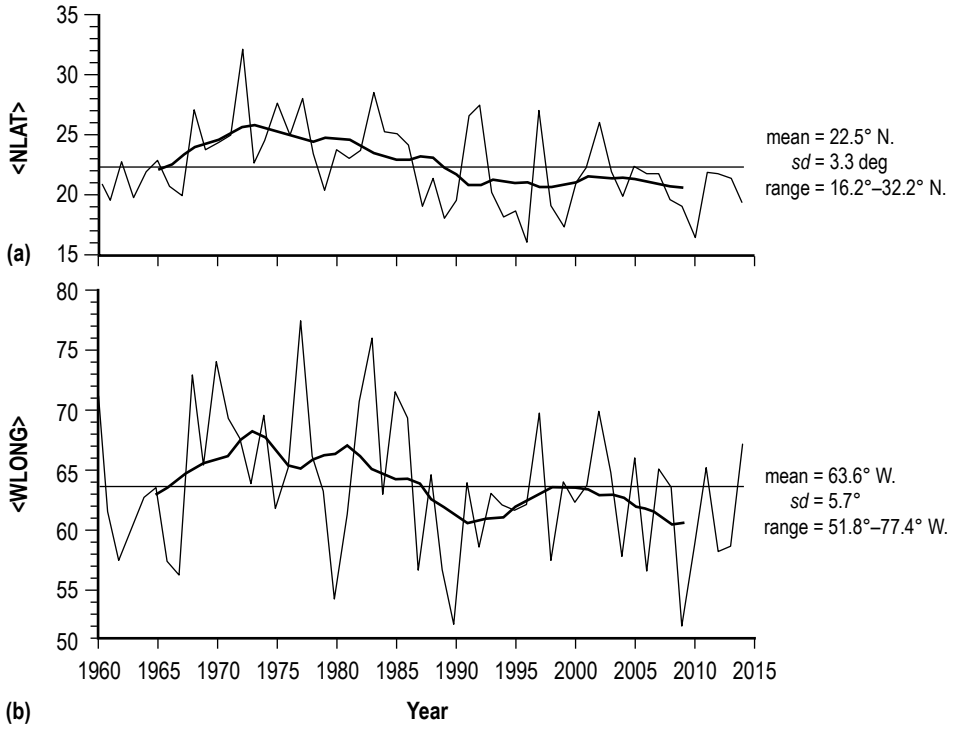


Figure 4. Annual and 10-yma variation of (a) <NLAT> and (b) <WLONG>.

Clearly, prior to the mid 1960s and from the late 1980s through the present, the 10-yma trend lines of <NLAT> and <WLONG> have been more southerly than the long-term mean of 22.5° N. and more easterly than the long-term mean of 63.6° W., respectively. Figure 5 displays the scatterplot of the year-tagged values of <NLAT> versus <WLONG> using the 10-yma trend values. The connecting lines demonstrate the year-to-year movement of the 10-yma parametric values. Obviously, for the interval of the late 1960s through the mid-to-late 1980s, the 10-yma values of <NLAT> and <WLONG> generally fall in the upper-right quadrant of the chart, while the interval from the mid-to-late 1980s through the present generally fall in the lower-left quadrant. Based on the Fisher's exact test of the observed 2×2 contingency table, the distribution of the 10-yma values of <NLAT> and <WLONG> (or those more suggestive of a departure from independence) has a probability of occurring purely by chance of only $P = 0.00001\%$. Hence, the apparently coordinated year-to-year movement of the 10-yma parametric values of <NLAT> and <WLONG> strongly suggests that the movement is not random, but instead is deterministic in nature (i.e., being driven by a cyclic or noncyclic climatic signal).

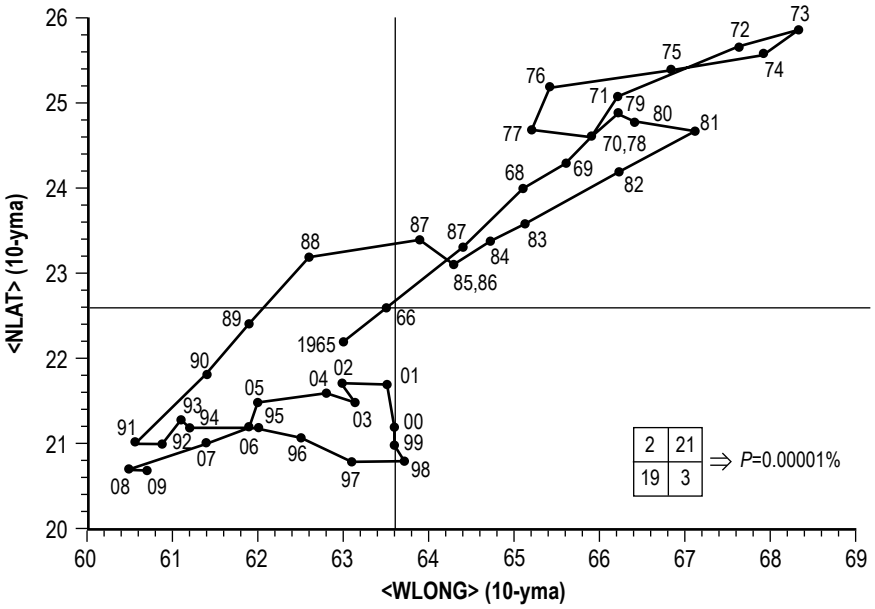


Figure 5. Scatterplot of <NLAT> versus <WLONG> using the 10-yma parametric values.

Figure 6 shows the annual and 10-yma variations of (a) <PWS>, (b) <LP>, (c) <PDI>, (d) <ACE>, and (e) <NSD>. Continuing the example from 1983, the four storms had individual PWSs of 100, 70, 65, and 55 kt, respectively, thus yielding <PWS> = 72.5 kt; the four storms had individual LPs of 963, 986, 994, and 999 mb, respectively, thus yielding <LP> = 985.5 mb; the four storms had individual PDIs of 4.9, 1.7, 2.4, and 1.8 (in units of 10^6 kt^3), respectively, thus yielding <PDI> = 2.7; the four storms had individual ACEs of 6.4, 3.1, 4.3, and 3.6 (in units of 10^4 kt^2), respectively, thus yielding <ACE> = 4.4; and the four storms had individual NSDs of 2.75, 3, 4, and 4 days, respectively, thus yielding <NSD> = 3.44 days. Overall, during the weather satellite era, the mean <PWS> = 73 kt, having $sd = 8.5$ kt and extremes of 53.2 kt (in 2013) and 97.7 kt (in

1961); <LP> = 980.7 mb, having *sd* = 7.6 mb and extremes of 957.0 mb (in 1961) and 996.6 mb (in 2013); <PDI> = 7.0, having *sd* = 3.8 and extremes of 1.3 (in 2013) and 18.3 (in 1961); <ACE> = 8.6, having *sd* = 3.7 and extremes of 2.7 (in 2013) and 18.7 (in 1961); and <NSD> = 4.94 days, having *sd* = 1.33 days and extremes of 2.46 days (in 1977) and 10.07 days (in 2010). From table 3, one finds that there are no statistically important differences in any of these particular parametric means for the two subintervals. (For any tropical cyclone, the NSD is simply the total amount of time the storm had wind speed ≥34 kt and the storm was not described as being extratropical. Likewise, the PDI and ACE indices for a particular tropical cyclone are merely the sums of the cubed and squared wind speed, respectively, for the storm while it is a tropical cyclone, in units of 10^6 kt^3 and 10^4 kt^2, respectively, determined from the 6-hr listings of wind speed found in the HURDAT2, with ACE typically being the more generally used parameter for measuring tropical cyclone energy.)

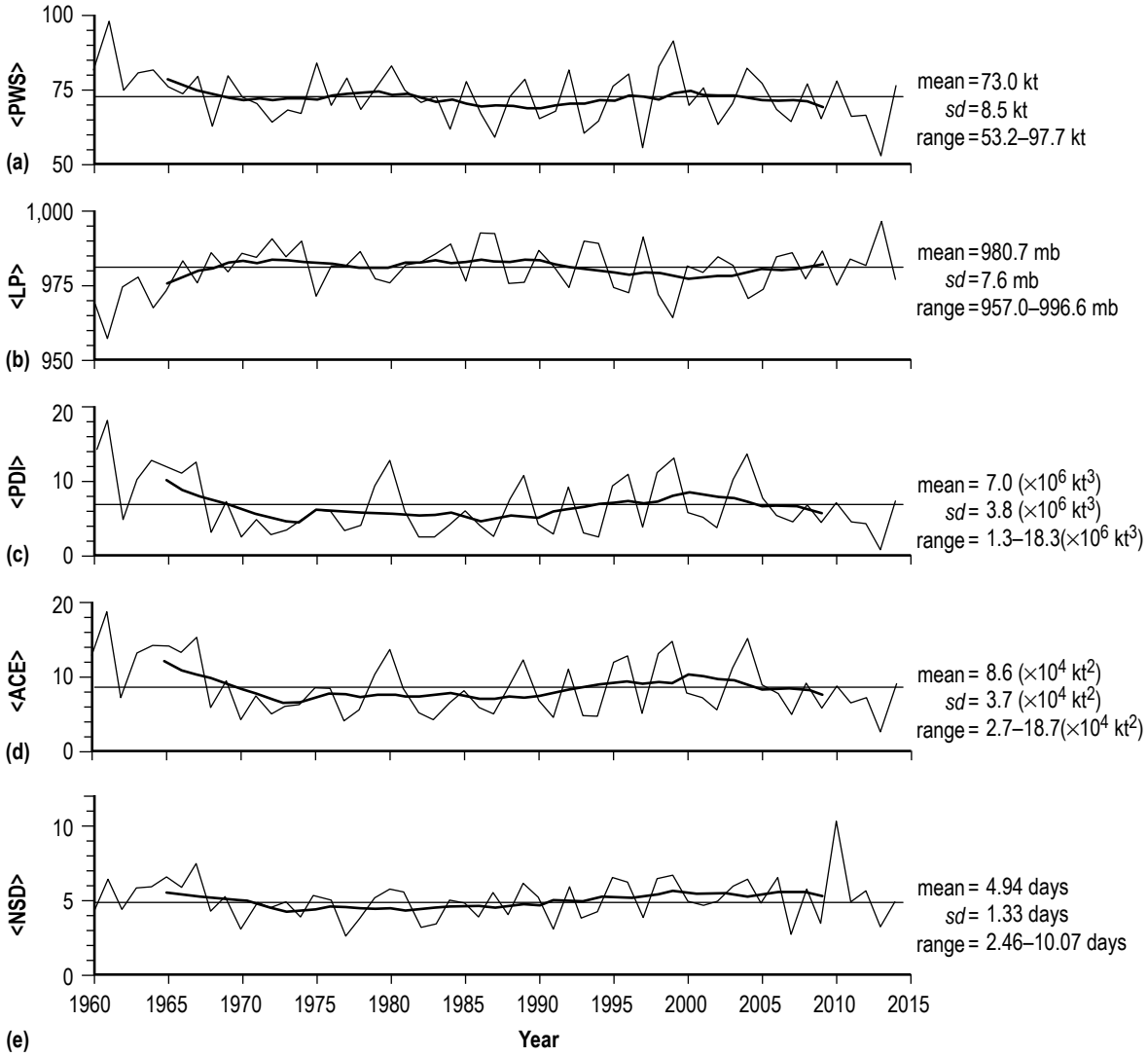


Figure 6. Annual and 10-yma variation of (a) <PWS>, (b) <LP>, (c) <PDI>, (d) <ACE>, and (e) <NSD>.

Figure 7 shows the annual and 10-yma values of (a) Sum PDI and (b) Sum ACE. Again, using the example of 1983, from above, one finds that the four storms had individual PDIs of 4.9, 1.7, 2.4, and 1.8 and individual ACEs of 6.4, 3.1. 4.3, and 3.6, respectively, thus yielding Sum PDI = 10.8 and Sum ACE = 17.4. From table 3, one finds important statistical differences to exist in the parametric means for the two subintervals for both Sum PDI and Sum ACE, with the current ongoing subinterval having the larger sums. Based on the 10-yma trends, the interval prior to the mid-1960s and since about 1993 have had Sum PDI and Sum ACE higher than their long-term means of 81.4 and 99.9, respectively, although the 10-yma trends appear to have peaked about the year 2000 and now seem to be in decline, likely dropping below the long-term means, perhaps, about the year 2016. The extremes of Sum PDI and Sum ACE are, respectively, 10.8 (in 1983) and 221.1 (in 2005) and 17.4 (in 1983) and 250.1 (in 2005).

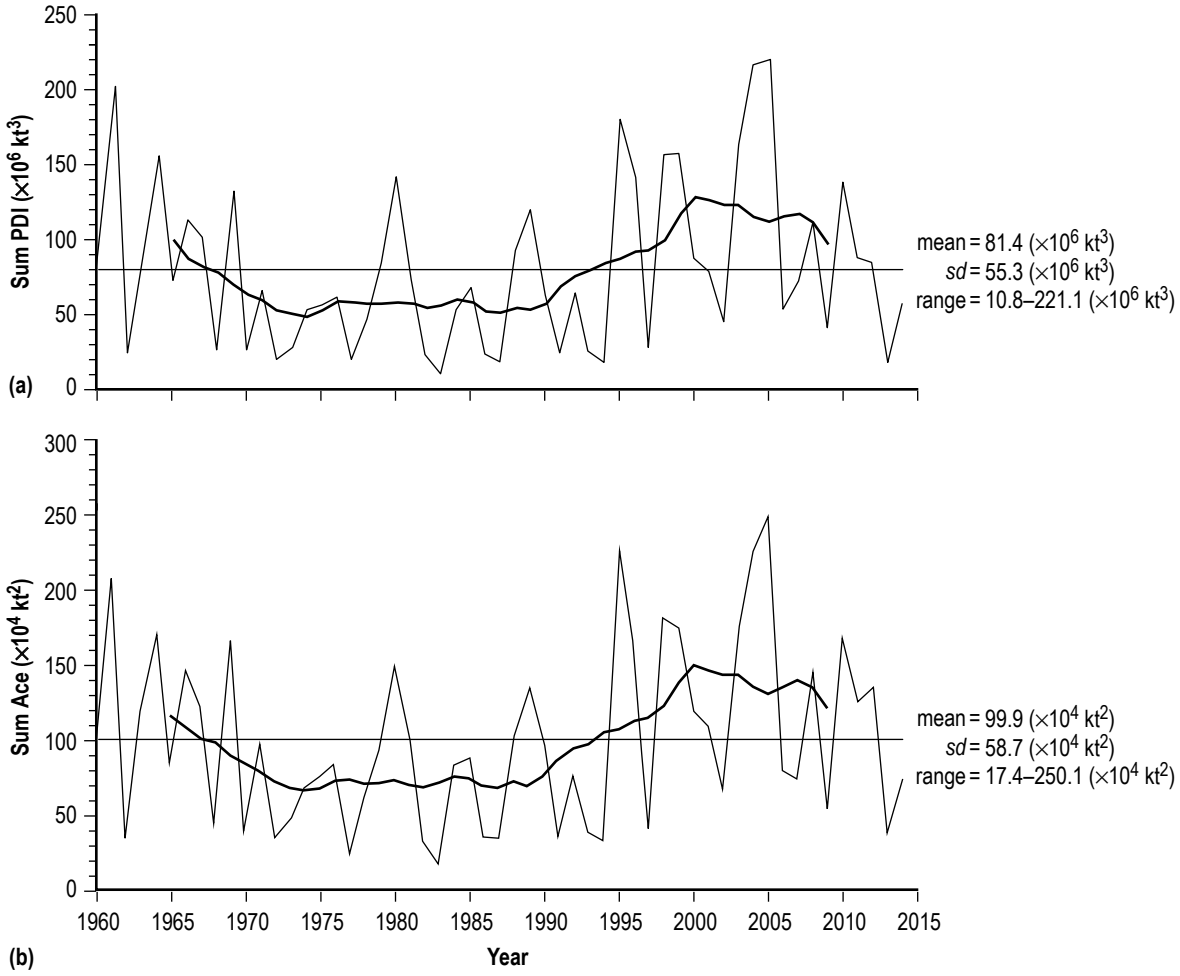


Figure 7. Annual and 10-yma variation of (a) Sum PDI and (b) Sum ACE.

Figure 8 displays the annual and 10-yma values of (a) Sum NSD, (b) Sum NHD, (c) Sum NMHD, and (d) NTCA. Important statistical differences in the parametric means for the two subintervals are found for all parameters, with the current ongoing subinterval having the higher parametric values. The extremes are 13.75 days (in 1983) and 191.25 days (in 2010); 3.25 days (in 2013)

and 61.25 days (in 1995); 0 days (in 1968, 1972, 1986, 1994, and 2013) and 24.5 days (in 1961); and 30.5% (in 1983) and 278.3% (in 2005), respectively. As with Sum PDI and Sum ACE, the 10-yma trends for Sum NSD, Sum NHD, Sum NMHD, and NTCA all now appear to be in decline. (NTCA is a simple formulation that compares tropical cyclone activity relative to the 1950–2000 base period; it was developed by Dr. Brian McNoldy and is available online at <http://andrew.rsmas.miami.edu/bmcnoldy/tropics/NTC.html>.)

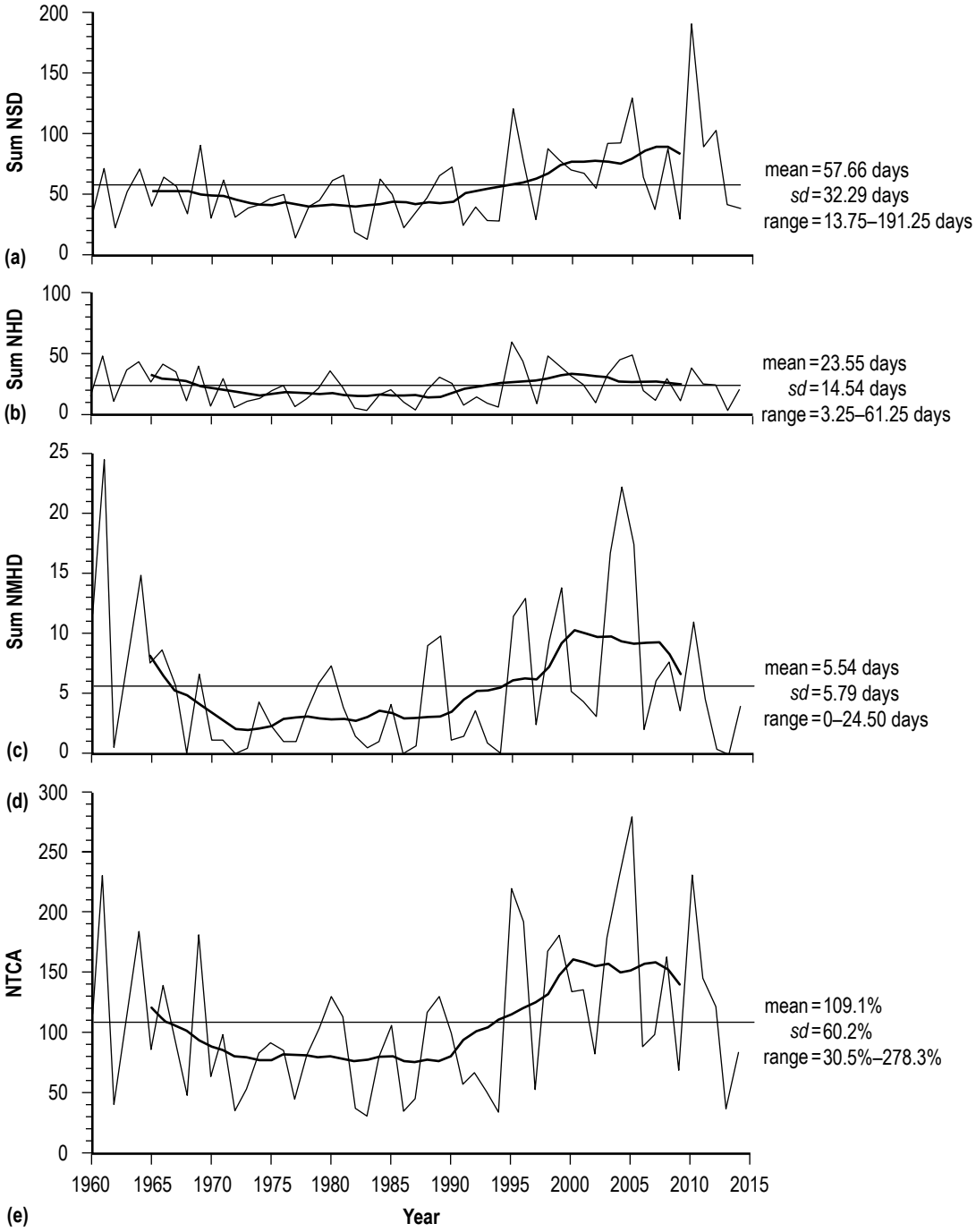


Figure 8. Annual and 10-yma variation of (a) Sum NSD, (b) Sum NHD, (c) Sum NMHD, and (d) NTCA.

Figure 9 depicts the annual and 10-yma LIS values of (a) NSD, (b) NHD, and (c) NMHD, identifying those storms having NSD ≥ 17 days, NHD ≥ 12 days, and NMHD ≥ 7 days. Ginger (in 1971) is the tropical cyclone having the largest LISNSD (21.25 days) and LISNHD (19.5 days), whereas Ivan (in 2004) had the largest LISNMHD (10 days). (The symbol * means that two storms had the same LISNHD and LISNMHD.)

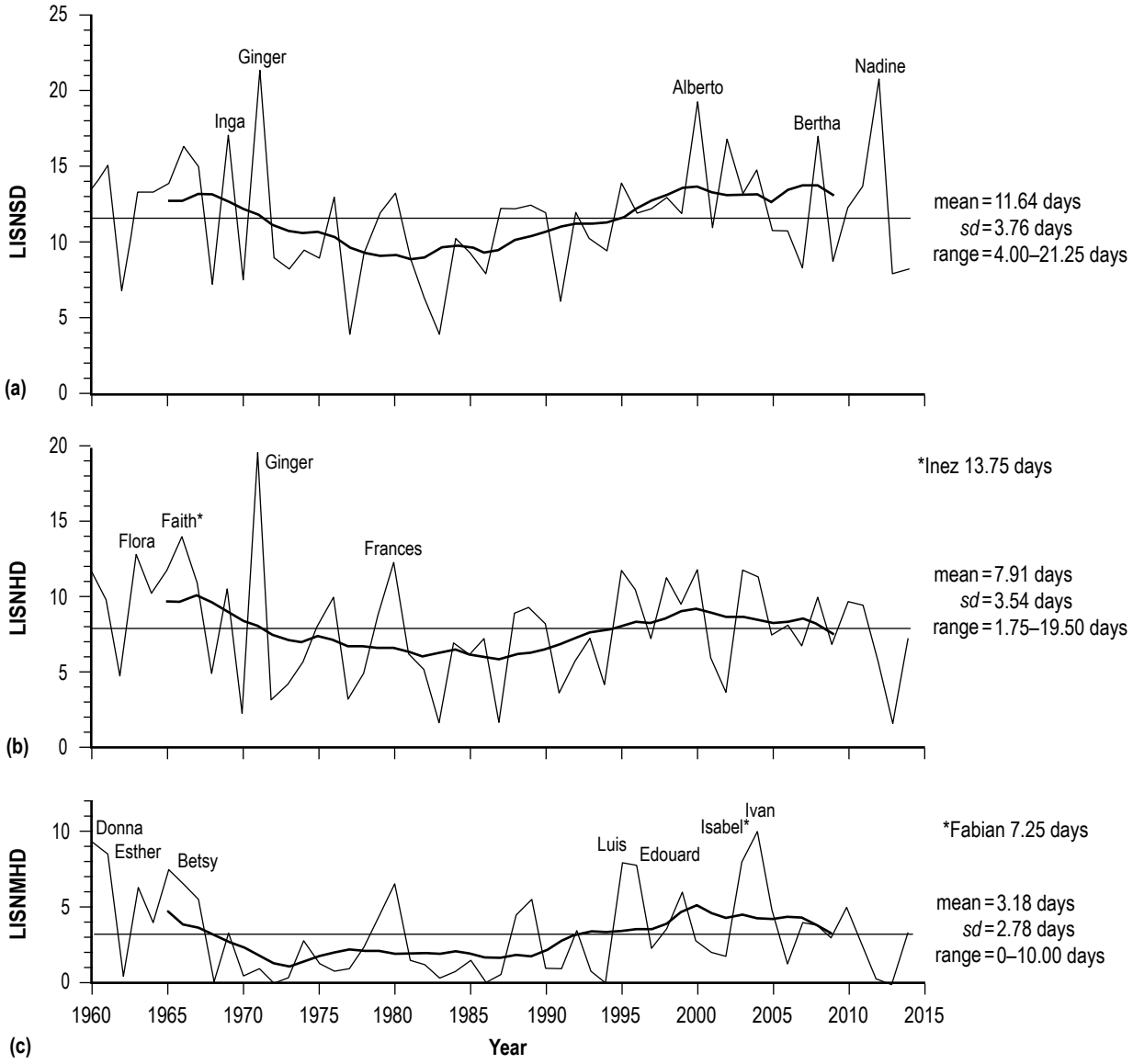


Figure 9. Annual and 10-yma LIS variation of (a) NSD, (b) NHD), and (c) NMHD.

Figure 10 shows the annual and 10-yma LIS values of (a) PWS, (b) LP, (c) PDI, and (d) ACE, identifying those storms having PWS ≥ 150 kt, LP ≤ 910 mb, PDI ≥ 50 ($\times 10^6$ kt^3), and ACE ≥50 ($\times 10^4$ kt^4). Camille (in 1969) and Allen (in 1980) are the tropical cyclones of highest PWS (165 kt); Wilma (in 2005) is the tropical cyclone of lowest LP (in 882 mb); and Ivan (in 2004) is the tropical cyclone having the highest PDI (83.5×10^6 kt^3) and ACE (70.4×10^4 kt^2).

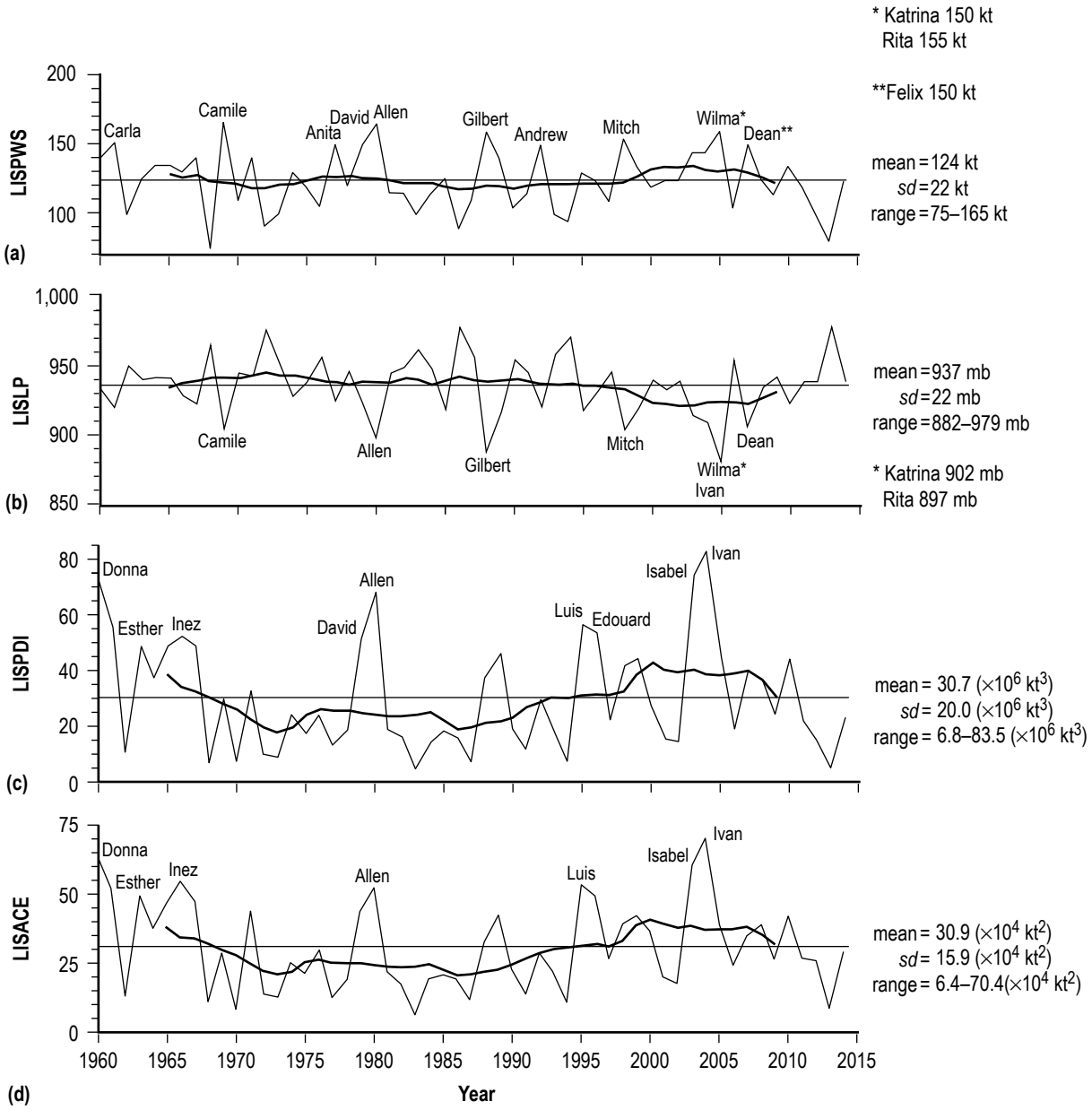


Figure 10. Annual and 10-yma LIS variation of (a) PWS, (b) LP, (c) PDI, and (d) ACE.

Figure 11 depicts the annual and 10-yma values of N4/5. The long-term mean is 1.4 tropical cyclones per year of category 4 or larger, with the range being 0 to 5 per year. The most (5) have occurred only twice, in 1999 and again in 2004. The least (0) has occurred 16 times. The 10-yma trend line was highest in 2003, but now appears to be in decline.

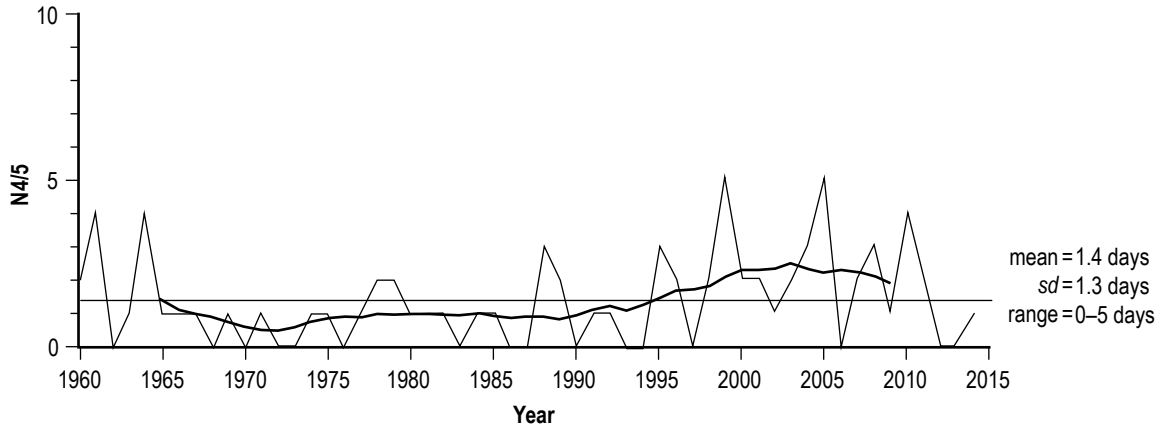


Figure 11. Annual and 10-yma variation of N4/5.

Table 4 identifies the LIS tropical cyclone parametric values and the storms that produced them. Table 5 gives the 10-yma values of the LIS parametric values.

Table 4. Summary of annual values of largest individual store parametric values.

Year	PWS	LP	PDI	ACE	NSD	NHD	NMHD	*N*(4/5)	Comment
1960	140	932	76.4	64.6	13.75	11.75	9.25	2	Donna (all), Ethel (PWS)
1961	150	920	55.5	52.2	15.00	9.75	8.50	4	Carla (PWS), Hattie (LP), Esther (PDI, ACE, NSD, NHD, NMHD), Debbie (NHD)
1962	100	950	10.5	13.7	6.75	4.75	0.50	–	Ella (PWS, LP, PDI, ACE, NSD, NMHD), Daisy (NHD)
1963	125	940	49.1	49.4	13.25	12.75	6.25	1	Flora (all)
1964	135	941	38.1	37.7	13.25	10.25	4.00	4	Cleo (PWS, PDI, ACE, NSD), Hilda (LP), Gladys (NHD), Dora (NMHD)
1965	135	941	48.8	47.0	13.75	11.75	7.50	1	Betsy (PWS, LP, PDI, ACE, NHD, NMHD), Carol (NSD)
1966	130	929	55.2	54.6	16.25	14.00	6.50	1	Inez (PWS, LP, PDI, ACE, NSD, NMHD), Faith (NHD)
1967	140	923	49.1	47.9	15.00	11.00	5.50	1	Beulah (PWS, LP, PDI, ACE, NSD, NMHD), Chloe (NHD)
1968	75	965	6.8	10.3	7.25	5.00	–	–	Gladys (PWS, LP, PDI, ACE, NHD), ST1 (NSD)
1969	165	905	29.8	28.9	17.00	10.50	3.25	1	Camile (PWS, LP, PDI), Debbie (ACE, NMHD), Inga (NSD, NHD)
1970	110	945	6.9	8.3	7.50	2.25	0.50	–	Celia (PWS, LP, PDI, NHD, NMHD), Ella (PWS, NMHD), Unnamed (ACE, NSD)
1971	140	943	32.8	44.2	21.25	19.50	1.00	1	Edith (PWS, LP, NMHD), Ginger (PDI, ACE, NSD, NHD)
1972	90	976	9.8	13.9	9.00	3.25	–	–	Betty (all)
1973	100	962	9.5	12.8	8.25	4.25	0.25	–	Ellen (all)
1974	130	928	24.7	25.6	9.50	5.75	2.75	1	Carmen (all)
1975	120	939	18.1	21.4	9.00	8.00	1.25	1	Gladys (all)
1976	105	957	23.9	30.0	13.00	10.00	0.75	–	Belle (PWS, LP, NMHD), Emmy (PDI, ACE, NSD, NHD)
1977	150	926	13.6	12.8	4.00	3.25	1.00	1	Anita (all)
1978	120	947	18.7	19.2	9.25	5.00	2.50	2	Ella (PWS, PDI, ACE, NHD, NMHD), Greta (LP), Flossie (NSD)
1979	150	924	51.3	44.0	13.00	8.75	4.50	2	David (PWS, LP, PDI, ACE, NHD, NMHD), Frederic (NSD)
1980	165	899	68.6	52.3	14.25	12.25	6.50	1	Allen (PWS, LP, PDI, ACE, NMHD), Frances (NSD, NHD)
1981	115	946	19.0	22.2	9.00	6.25	1.50	1	Harvey (PWS, LP), Irene (PDI, ACE, NSD, NHD, NMHD), Dennis (NSD)
1982	115	950	16.6	18.2	6.25	5.25	1.25	1	Debby (all)
1983	100	963	4.9	6.4	4.00	1.75	0.25	–	Alicia (PWS, LP, PDI, ACE, NHD, NMHD), Chantal (NSD), Dean (NSD)
1984	115	949	14.1	19.5	10.25	7.00	0.75	1	Diana (PWS, LP, NMHD), Josephine (PDI, ACE, NSD, NHD)
1985	125	920	18.6	21.2	9.25	6.25	1.50	1	Gloria (all), Elena (NMHD)
1986	90	979	16.0	19.7	8.00	7.25	–	–	Earl (PWS, LP, PDI, ACE, NSD, NHD))
1987	110	958	7.7	11.9	12.25	1.75	0.50	–	Emily (PWS, LP, PDI, NHD, NMHD), Arlene (ACE, NSD, NHD)

Table 4. Summary of annual values of largest indiidual store parametric values (Continued).

Year	PWS	LP	PDI	ACE	NSD	NHD	NMHD	*N*(4/5)	Comment
1988	160	888	38.0	32.8	12.25	9.00	4.50	3	Gilbert (PWS, LP, ACE, NMHD), Joan (NSD), Helene (NHD)
1989	140	918	46.3	42.7	12.50	9.25	5.50	2	Hugo (PWS, LP, PDI, ACE, NMHD), Gabrielle (NSD, NHD)
1990	105	956	19.3	23.0	12.00	8.25	1.00	–	Gustav (PWS, LP, PDI, ACE, NMHD), Isidore (NSD, NHD)
1991	115	946	12.0	14.0	6.25	3.75	1.00	1	Claudette (all)
1992	150	922	31.5	28.4	12.00	5.75	3.50	1	Andrew (PWS, LP, PDI, ACE, NMHD), Bonnie (NSD, NHD)
1993	100	960	17.5	22.1	10.25	7.25	0.75	–	Emily (all)
1994	95	972	8.1	10.9	9.50	4.25	–	–	Florence (PWS, LP, PDI, ACE, NHD), Gordon (NSD)
1995	130	919	57.3	53.5	14.00	11.75	8.00	3	Opal (PWS, LP), Luis (PDI, ACE, NHD, NMHD), Felix (NSD)
1996	125	933	54.3	49.3	12.00	10.50	7.75	2	Edouard (all)
1997	110	946	22.3	26.6	12.25	7.25	2.25	–	Erika (all)
1998	155	905	42.5	39.4	13.00	11.25	3.75	2	Mitch (PWS, LP, PDI, NMHD), Georges (ACE, NSD, NHD)
1999	135	921	44.9	42.3	12.00	9.50	6.00	5	Floyd (PWS, LP), Lenny (PWS), Gert (PDI, ACE, NHD, NMHD), Dennis (NSD)
2000	120	941	28.1	36.9	19.25	11.75	2.75	2	Keith (PWS, LP), Isaac (PWS, NMHD), Alberto (PDI, ACE, NSD, NHD)
2001	125	934	15.7	20.1	11.00	6.00	2.00	2	Iris (PWS), Michelle (LP, PDI, NMHD), Erin (ACE, NSD, NHD)
2002	125	940	15.0	17.8	16.75	3.75	1.75	1	Lili (PWS), Isidore (LP,PDI, ACE, NHD, NMHD), Kyle (NSD)
2003	145	915	75.2	63.3	13.25	11.75	8.00	2	Isabel (all)
2004	145	910	83.5	70.4	14.75	11.50	10.00	3	Ivan (all)
2005	160	882	45.7	38.9	10.75	7.50	4.75	5	Wilma (PWS, LP, PDI, ACE, NHD, NMHD), Ophelia (NSD)
2006	105	955	19.4	24.3	10.75	8.25	1.25	–	Helene (PWS, LP, PDI, ACE, NSD, NHD), Gordon (PWS, LP, NMHD)
2007	150	907	40.8	35.2	8.50	6.75	4.00	2	Dean (all), Felix (PWS)
2008	125	935	37.7	39.2	17.00	10.00	4.25	3	Ike (PWS, LP, PDI, ACE, NHD, NMHD), Gustav (PWS), Paloma (PWS), Bertha (NSD)
2009	115	943	25.3	26.5	8.75	7.00	3.00	1	Bill (all)
2010	135	924	44.5	41.9	12.25	9.75	5.00	4	Igor (all)
2011	120	940	22.5	27.0	13.75	9.50	2.75	2	Ophelia (PWS, LP, NMHD), Katia (PWS, PDI, ACE, NHD), Philippe (NSD)
2012	100	940	15.6	26.3	20.75	5.75	0.25	–	Sandy (PWS, LP, NHD), Michael (PWS, NMHD), Nadine (PDI, ACE, NSD)
2013	80	979	5.3	8.9	8.00	1.75	–	–	Humberto (PWS, LP, PDI, ACE, NSD, NHD)
2014	125	940	28.7	29.7	8.25	7.25	3.25	1	Gonzalo (all)
count								75	
mean	124	937	30.7	30.9	11.64	7.91	3.18	1.4	
sd	22	22	20.0	15.9	3.76	3.54	2.78	1.3	

Table 5. Summary of 10-yma values of largest individual storm parametric values.

Year	LISPWS	LISLP	LISPDI	LISACE	LISNSD	LISNHD	LISNMHD	*N*(4/5)
1965	128.0	935.3	38.5	37.8	12.81	9.68	4.69	1.40
1966	126.0	937.1	33.8	34.6	12.81	9.69	3.88	1.15
1967	125.0	939.5	32.7	34.2	13.24	10.10	3.48	1.00
1968	123.3	941.9	30.7	32.4	13.10	9.60	3.15	0.95
1969	121.8	942.4	28.0	30.0	12.66	8.95	2.79	0.75
1970	120.8	941.6	25.8	28.1	12.24	8.54	2.41	0.60
1971	118.8	942.9	22.7	25.6	11.84	8.15	1.81	0.55
1972	118.0	944.5	19.4	22.6	11.13	7.56	1.30	0.50
1973	120.8	943.7	18.2	21.3	10.68	7.18	1.20	0.60
1974	122.3	943.8	19.9	22.5	10.58	7.09	1.39	0.75
1975	124.3	942.4	24.0	25.4	10.71	7.50	1.75	0.85
1976	125.8	940.3	26.4	26.5	10.44	7.34	2.08	0.90
1977	125.8	939.1	26.1	25.6	9.69	6.78	2.16	0.95
1978	127.0	937.9	26.2	25.5	9.34	6.75	2.23	1.00
1979	126.3	939.0	25.4	24.9	9.16	6.69	2.13	1.00
1980	125.8	939.1	24.9	24.6	9.21	6.66	2.04	1.00
1981	125.3	939.2	24.5	24.1	8.98	6.44	2.01	1.00
1982	122.5	941.9	23.8	23.5	9.14	6.22	1.95	0.95
1983	122.5	940.6	24.5	24.1	9.70	6.35	2.03	0.95
1984	124.0	937.3	25.2	24.8	9.83	6.58	2.18	1.00
1985	120.5	939.9	22.5	23.2	9.69	6.40	1.95	0.95
1986	117.5	942.7	19.7	21.4	9.44	6.08	1.65	0.90
1987	119.3	941.3	20.1	21.5	9.59	5.98	1.74	0.90
1988	121.0	939.8	21.5	22.7	10.19	6.28	1.88	0.90
1989	120.0	940.8	21.8	23.1	10.46	6.41	1.86	0.85
1990	119.3	941.9	23.4	24.3	10.66	6.55	2.15	0.90
1991	121.3	939.5	27.3	27.4	11.10	6.99	2.84	1.10
1992	123.0	936.6	29.9	29.6	11.30	7.43	3.34	1.20
1993	122.8	936.9	30.9	30.7	11.34	7.81	3.39	1.15
1994	122.3	937.9	31.0	31.0	11.35	7.94	3.38	1.25
1995	122.8	937.3	31.4	31.6	11.69	8.13	3.49	1.50
1996	124.0	935.9	32.0	32.6	12.29	8.41	3.63	1.65
1997	123.3	936.2	31.4	32.2	12.76	8.43	3.59	1.70
1998	124.3	934.9	33.5	34.0	13.15	8.55	3.86	1.80
1999	129.0	929.5	40.1	39.0	13.56	9.14	4.73	2.05
2000	133.0	924.6	43.3	41.2	13.66	9.29	5.06	2.30
2001	133.5	923.8	41.0	39.3	13.44	8.96	4.58	2.30
2002	134.5	923.0	40.2	38.4	13.19	8.83	4.34	2.30
2003	135.0	922.5	40.8	38.9	13.20	8.74	4.45	2.45
2004	132.5	925.1	39.6	38.1	13.24	8.55	4.33	2.30
2005	132.3	925.4	39.5	37.5	12.73	8.33	4.29	2.20
2006	132.8	924.8	40.6	38.1	13.51	8.40	4.44	2.30
2007	131.3	925.1	41.0	38.9	13.85	8.68	4.40	2.25
2008	126.8	928.3	37.5	36.6	13.79	8.28	3.93	2.10
2009	122.5	933.0	31.3	31.8	13.20	7.56	3.19	1.90
mean	124.9	936.7	29.6	29.8	11.55	7.78	2.96	1.31
sd	4.7	6.6	7.3	6.2	1.59	1.14	1.12	0.59

2.2 Climatic Factors

Tables 6 and 7, respectively, provide convenient listings of the yearly and 10-yma values of the D–M and J–N averages of the five climatic factors that are being examined in relation to tropical cyclone activity in this study, including <ONI>, <AMO>, <AMM>, <GLOTI>, and <QBO>. Monthly values of ONI are available online at <http://www.esrl.noaa.gov/psd/data/correlation/oni.data>; monthly values of AMO are available online at <http://www.esrl.noaa.gov/psd/data/correlation/amon.us.data>; monthly values of AMM are available online at <http://www.esrl.noaa.gov/psd/data/timeseries/monthly/AMM/ammsst.data>; monthly values of GLOTI are available online at <http://data.giss.nasa.gov/gistemp/tabledata_v3/GLB.Ts+dSST.txt>; and monthly values of QBO (30 mb) are available online at <http://www.esrl.noaa.gov/psd/data/correlation/qbo.data>.

Table 6. Summary of yearly climate parametric means.

	<ONI>		<AMO>		<AMM>		<GLOTI>		<QBO>	
Year	D–M	J–N	D–M	J–N	D–M	J–N	D–M	J–N	D–M	J–N
1960	–0.12	0.12	0.176	0.291	1.16	1.04	–0.09	–0.02	1.91	–14.16
1961	0.07	–0.04	0.152	0.036	0.59	0.43	0.13	0.05	–1.20	7.10
1962	–0.24	–0.18	0.142	0.006	2.44	1.35	0.03	0.03	2.74	–14.64
1963#	–0.06	1.03	0.122	–0.071	2.02	–2.01	–0.01	0.16	–19.14	–1.80
1964&	0.35	–0.73	–0.019	–0.161	–0.32	0.54	–0.16	–0.19	5.40	0.26
1965#	–0.15	1.51	–0.118	–0.201	–0.84	–2.29	–0.15	–0.09	–2.63	–17.68
1966	1.02	0.07	–0.015	–0.011	1.50	0.40	–0.06	–0.02	–11.93	8.75
1967	–0.39	–0.14	0.013	–0.170	0.56	–0.26	–0.01	–0.01	10.27	–4.99
1968	–0.54	0.48	–0.170	–0.168	–0.34	–1.56	–0.03	–0.05	–10.27	–17.87
1969#	0.98	0.70	0.058	–0.055	2.58	0.63	–0.01	0.07	–2.29	9.17
1970&	0.42	–0.60	–0.005	–0.172	3.82	0.89	0.13	0.02	–3.37	–20.42
1971&	–1.02	–0.77	–0.288	–0.320	–0.94	–1.55	–0.10	–0.05	–3.38	8.57
1972#	–0.13	1.48	–0.362	–0.340	–2.28	–4.70	–0.07	0.08	6.04	–17.92
1973&	0.87	–1.30	–0.304	–0.149	–5.03	–2.17	0.26	0.10	–0.55	6.18
1974&	–1.43	–0.59	–0.358	–0.465	–3.82	–3.99	–0.10	–0.03	–1.75	–20.95
1975&	–0.63	–1.31	–0.323	–0.284	–2.84	–1.46	0.07	–0.08	–11.94	8.85
1976	–0.98	0.43	–0.413	–0.300	–1.62	0.17	–0.14	–0.14	10.06	–4.55
1977#	0.48	0.54	–0.274	–0.146	–1.15	–1.56	0.17	0.12	–15.15	–9.65
1978*	0.27	–0.29	–0.155	–0.211	1.56	–0.25	0.08	0.01	7.59	6.07
1979	0.10	0.25	–0.170	–0.074	1.59	0.27	0.05	0.13	–1.36	–21.89
1980	0.40	0.10	–0.009	0.002	3.26	1.45	0.31	0.19	–4.52	10.60
1981	–0.39	–0.28	–0.112	–0.084	3.01	0.48	0.33	0.20	7.29	–7.45
1982#	0.12	1.31	–0.082	–0.282	0.21	–1.91	0.10	0.07	–14.50	–0.75
1983	1.64	–0.28	–0.094	–0.112	–1.64	–0.03	0.37	0.22	11.75	–5.83
1984	–0.45	–0.46	–0.086	–0.277	–2.01	–3.18	0.18	0.08	–12.67	–21.91
1985	–0.86	–0.49	–0.328	–0.189	–3.53	–0.41	0.05	0.07	4.44	11.87
1986#	–0.29	0.57	–0.278	–0.265	–4.02	–2.93	0.22	0.06	8.84	–7.47

Table 6. Summary of yearly climate parametric means (Continued).

	<ONI>		<AMO>		<AMM>		<GLOTI>		<QBO>	
Year	D–M	J–N	D–M	J–N	D–M	J–N	D–M	J–N	D–M	J–N
1987#	1.16	1.43	–0.112	0.177	–1.78	0.60	0.22	0.29	–13.72	–1.93
1988&	0.25	–1.39	0.032	–0.005	–0.26	0.65	0.42	0.31	6.72	–1.80
1989	–1.26	–0.30	–0.186	0.021	–3.46	1.00	0.23	0.24	–2.98	–16.56
1990	0.16	0.31	–0.143	0.049	–0.27	1.16	0.44	0.34	–1.81	12.54
1991#	0.31	0.81	–0.099	–0.133	–2.18	–2.24	0.39	0.38	8.56	–11.14
1992	1.35	0.05	–0.149	–0.275	–1.16	0.02	0.34	0.06	–15.26	–3.43
1993	0.36	0.24	–0.198	–0.218	–2.47	–2.85	0.28	0.14	11.03	–0.87
1994#	0.18	0.58	–0.247	–0.137	–5.49	–2.15	0.21	0.32	–11.25	–18.07
1995	0.67	–0.48	0.045	0.207	–1.60	2.97	0.45	0.42	9.64	7.76
1996	–0.63	–0.29	–0.002	–0.076	2.11	–0.05	0.32	0.32	–8.86	–22.39
1997#	–0.10	1.86	–0.022	0.083	2.87	–0.09	0.38	0.50	2.57	11.39
1998&	1.50	–0.93	0.275	0.450	0.44	2.34	0.66	0.57	–4.98	–19.89
1999&	–1.19	–1.15	0.129	0.157	–0.28	0.98	0.44	0.38	7.11	11.51
2000&	–1.28	–0.63	0.041	0.045	0.23	–0.55	0.46	0.37	4.00	–13.48
2001	–0.52	–0.08	–0.031	0.219	–0.47	1.91	0.46	0.55	–16.75	–16.40
2002#	0.08	0.94	0.132	0.040	1.88	–1.44	0.68	0.57	8.61	9.16
2003	0.55	0.30	0.082	0.351	–1.39	1.63	0.56	0.59	–4.80	–21.01
2004#	0.21	0.62	0.171	0.256	2.29	3.11	0.59	0.47	2.55	8.35
2005	0.43	–0.02	0.234	0.353	3.05	4.05	0.61	0.68	–3.54	–26.13
2006	–0.54	0.47	0.182	0.368	2.09	1.83	0.55	0.62	–6.69	10.41
2007&	0.24	–0.73	0.178	0.136	1.74	0.74	0.73	0.57	–1.13	–26.41
2008	–1.19	–0.30	0.126	0.176	0.55	0.97	0.44	0.53	–2.74	11.69
2009#	–0.46	0.80	–0.074	0.152	–1.28	0.40	0.53	0.64	9.27	–11.91
2010&	1.02	–1.15	0.265	0.425	3.90	4.93	0.73	0.62	–19.68	–0.65
2011&	–0.98	–0.54	0.146	0.112	3.43	2.09	0.50	0.59	10.23	–1.77
2012	–0.56	0.30	0.047	0.361	0.78	2.85	0.52	0.62	–17.33	–25.28
2013	–0.37	–0.28	0.150	0.213	2.91	2.28	0.53	0.64	1.09	13.26
2014	–0.36	0.25	–0.021	0.234	–1.70	0.21	0.65	0.68	10.01	–20.94
mean	–0.04	0.03	–0.043	–0.008	–0.03	0.09	0.27	0.25	–1.46	–5.39
sd	0.73	0.76	0.178	0.223	2.34	1.97	0.26	0.26	9.06	12.73

* = ST1, an SS/TS that originated 01/19/1978 and ended on 01/22/1978 having PWS = 40 kt, LP =1,002, NSD = 3 days, and a genesis location of 23.5° N., 64.6° W., is considered a statistical outlier; consequently, it is ignored in this analysis.

= ENL season; i.e., <ONI> (J–N) = 0.5 or more positive in value.

& = LNL season; i.e., <ONI> (J–N) = –0.5 or more negative in value.

Table 7. Summary of 10-yma climate parametric means.

	<ONI>		<AMO>		<AMM>		<GLOTI>		<QBO>	
Year	D–M	J–N	D–M	J–N	D–M	J–N	D–M	J–N	D–M	J–N
1965	0.12	0.25	0.025	–0.074	1.07	–0.18	–0.03	–0.01	–2.98	–4.90
1966	0.09	0.17	–0.006	–0.115	1.12	–0.29	–0.03	–0.01	–3.35	–5.14
1967	0.04	0.22	–0.053	–0.150	0.81	–0.69	–0.04	–0.01	–3.30	–5.23
1968	0.09	0.19	–0.100	–0.171	0.22	–1.00	–0.03	–0.01	–2.20	–4.99
1969	0.05	0.08	–0.138	–0.190	–0.30	–1.23	–0.02	–0.01	–1.63	–5.66
1970	–0.06	–0.06	–0.165	–0.210	–0.58	–1.42	–	–	–2.45	–5.39
1971	–0.19	–0.18	–0.195	–0.228	–0.84	–1.39	–	–	–1.82	–4.73
1972	–0.24	–0.13	–0.230	–0.241	–1.08	–1.47	0.01	–	–1.99	–5.63
1973	–0.16	–0.13	–0.243	–0.242	–1.07	–1.46	0.02	0.01	–2.37	–4.66
1974	–0.16	–0.19	–0.254	–0.245	–1.02	–1.42	0.03	0.01	–1.43	–5.02
1975	–0.21	–0.18	–0.265	–0.237	–1.10	–1.41	0.04	0.02	–1.44	–5.02
1976	–0.18	–0.12	–0.257	–0.217	–0.93	–1.28	0.07	0.05	–0.96	–4.27
1977	–0.13	–0.11	–0.234	–0.202	–0.61	–1.04	0.10	0.06	–1.46	–4.21
1978	–0.08	–0.06	–0.210	–0.197	–0.31	–0.79	0.12	0.06	–1.87	–3.95
1979	0.01	–0.01	–0.185	–0.186	–0.05	–0.64	0.14	0.07	–1.80	–4.60
1980	0.04	0.04	–0.172	–0.172	–	–0.55	0.15	0.09	–1.53	–4.50
1981	0.07	0.09	–0.166	–0.166	–0.15	–0.65	0.17	0.11	–0.77	–4.50
1982	0.14	0.14	–0.151	–0.148	–0.30	–0.70	0.19	0.12	–0.76	–4.21
1983	0.17	0.13	–0.133	–0.121	–0.43	–0.55	0.21	0.15	–0.73	–4.26
1984	0.10	0.05	–0.125	–0.106	–0.77	–0.46	0.23	0.17	–0.85	–4.39
1985	0.02	0.03	–0.132	–0.099	–1.20	–0.44	0.25	0.18	–0.80	–4.03
1986	0.04	0.10	–0.138	–0.099	–1.63	–0.59	0.26	0.20	–0.60	–4.11
1987	0.14	0.09	–0.141	–0.101	–1.96	–0.63	0.27	0.21	–0.58	–4.43
1988	0.14	0.05	–0.150	–0.106	–2.07	–0.68	0.28	0.20	–0.65	–4.32
1989	0.10	0.13	–0.163	–0.105	–2.29	–0.77	0.28	0.21	–0.61	–3.88
1990	0.21	0.18	–0.152	–0.077	–2.37	–0.55	0.30	0.24	–0.28	–3.89
1991	0.27	0.14	–0.120	–0.048	–1.96	–0.23	0.33	0.27	–0.91	–4.84
1992	0.19	0.12	–0.101	–0.044	–1.42	–0.12	0.34	0.29	–0.98	–4.92
1993	0.19	0.16	–0.085	–0.026	–1.16	–0.07	0.36	0.32	–0.75	–5.16
1994	0.26	0.14	–0.057	0.004	–0.96	0.01	0.38	0.34	–0.83	–4.66
1995	0.19	0.05	–0.032	0.011	–0.78	–0.08	0.39	0.34	–0.03	–4.56
1996	0.08	–0.04	–0.019	0.028	–0.67	0.05	0.40	0.35	–1.01	–6.12
1997	–0.03	–0.04	–0.002	0.061	–0.43	0.18	0.42	0.39	–1.08	–5.76
1998	–0.08	0.01	0.026	0.105	–0.22	0.82	0.45	0.44	–0.68	–6.14
1999	–0.07	0.01	0.061	0.154	0.22	1.14	0.48	0.47	–0.78	–5.82
2000	–0.08	0.04	0.091	0.181	0.84	1.28	0.51	0.49	–0.75	–6.19
2001	–0.09	0.10	0.110	0.210	1.07	1.42	0.53	0.52	–1.30	–6.25
2002	–0.07	0.01	0.129	0.235	1.01	1.39	0.56	0.53	–0.65	–6.50
2003	–0.19	–0.09	0.132	0.224	0.96	0.82	0.56	0.54	–1.45	–6.81
2004	–0.28	0.04	0.114	0.210	0.92	1.29	0.56	0.55	–1.23	–6.40
2005	–0.13	0.11	0.115	0.229	1.05	1.54	0.57	0.57	–2.31	–6.93
2006	–0.04	0.06	0.135	0.242	1.43	1.82	0.59	0.59	–2.14	–5.56
2007	–0.10	0.01	0.140	0.253	1.57	2.05	0.58	0.59	–2.09	–6.55
2008	–0.17	–0.05	0.139	0.262	1.73	2.29	0.57	0.60	–3.09	–6.56
2009	–0.25	–0.10	0.133	0.254	1.75	2.18	0.58	0.61	–2.42	–6.31
mean	–0.01	0.03	–0.072	–0.037	–0.29	–0.11	0.27	0.24	–1.42	–5.15
sd	0.15	0.11	0.131	0.170	1.13	1.09	0.21	0.21	0.83	0.89
median	0.01	0.04	–0.120	–0.099	–0.43	–0.46	0.27	0.20	–1.23	–4.99

Figure 12 depicts the annual and 10-yma variation of the 6-month averages of <ONI> for (a) D–M) and (b) J–N. The dashed lines represent thresholds for marking the occurrences of El Niño-like (ENL) and La Niña-like (LNL) conditions in the Niño 3.4 region of the Pacific Ocean, a region ±5º north and south of the equator and ±25º either side of 145º W. longitude. For <ONI> (D–M), its mean is –0.04 ºC, having *sd* = 0.73 ºC and range of –1.43 (in 1974) to 1.64 ºC (in 1983). Ten years are found to be reflective of ENL conditions (i.e., <ONI> ≥0.5 ºC), including 1966, 1969, 1973, 1983, 1987, 1992, 1995, 1998, 2003, and 2010, while 15 years are found to be reflective of LNL conditions (<ONI> ≤–0.5 ºC), including 1968, 1971, 1974, 1975, 1976, 1985, 1989, 1996, 1999, 2000, 2001, 2006, 2008, 2011, and 2012. All other years (30) are reflective of neutral conditions (i.e., <ONI> is not reflective of either ENL or LNL). For <ONI> (J–N), its mean is 0.03 ºC, having *sd* = 0.76 ºC and range –1.39 (in 1988) to 1.86 ºC (in 1997). Fourteen years are found to be reflective of ENL conditions, including 1963, 1965, 1969, 1972, 1977, 1982, 1986, 1987, 1991, 1994, 1997, 2002, 2004, and 2009, while 13 years are found to be reflective of LNL conditions, including 1964, 1970, 1971, 1973, 1974, 1975, 1988, 1998, 1999, 2000, 2007, 2009, and 2010. All other years (28) are reflective of neutral conditions.

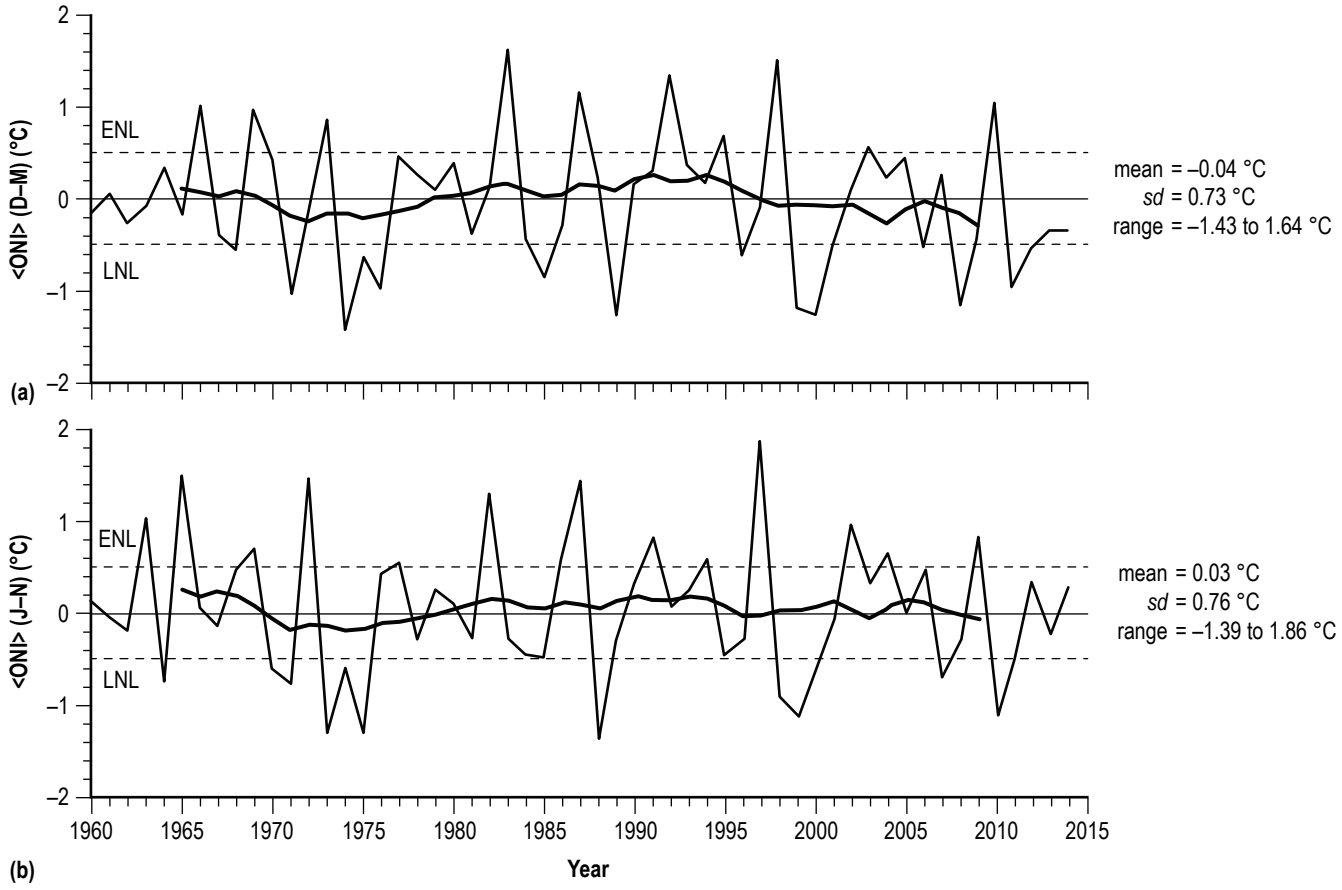


Figure 12. Annual and 10-yma variation of 6-month averages of <ONI> for (a) D–M and (b) J–N.

Figure 13 shows the scatterplot of <ONI> (J–N) versus <ONI> (D–M). Plainly, there is no preferential coupling between the preceding <ONI> (D–M) and the following <ONI> (J–N) values reflective of ENL or LNL conditions. Of the 10 years having ENL conditions in D–M, only two of the years also had ENL conditions in J–N: 1969 and 1987. Of the 15 years having LNL conditions in D–M, only five of the years also had LNL conditions in J–N: 1971, 1974, 1975, 1999, and 2000. Now, the 2015 <ONI> (D–M) = 0.61 ºC, indicative of ENL conditions. The June ONI monthly value measures 1.01 ºC, indicative of an ongoing strong El Niño. In fact, the National Oceanic and Atmospheric Administration (NOAA) predicts that the current ongoing El Niño likely will persist for some time, through the 2015 hurricane season and possibly even to spring 2016 (<http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/enso_advisory/ensodisc.pdf>). Therefore, it seems highly probable that the <ONI> (J–N) value undoubtedly will be reflective of ENL conditions, rather than non-ENL conditions, in particular, like that experienced in 1987 (1.43 ºC) or possibly, like that experience in 1997, the strongest (1.86 ºC) on record since 1950. (<ONI> (J–N) = 1.63 ºC for 2015, the second highest reading since 1950.)

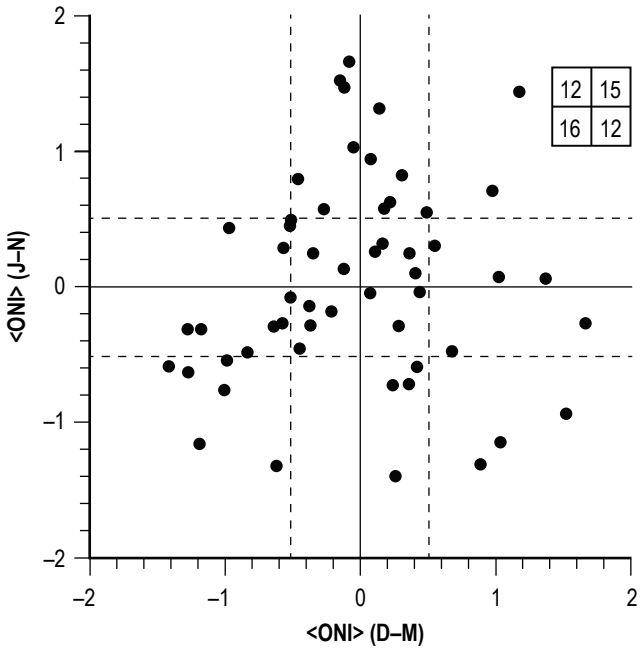


Figure 13. Scatterplot of <ONI> (J–N) versus <ONI> (D–M) using annual parametric values.

Figure 14 displays the annual and 10-yma variation of the 6-month averages of <AMO> for (a) D–M and (b) J–N. The AMO is an oceanic index that is defined as a fluctuation in the detrended sea surface temperature of the North Atlantic Ocean, north of the equator (i.e., 0–70º N. latitude). As with the ONI, the AMO fluctuates between warm (positive) and cold (negative) phases, but with the AMO fluctuation being of much longer duration (about 65–70 years in length). For the weather satellite era, the long-term mean of <AMO> (D–M) is –0.043 ºC, having *sd* = 0.178 ºC and range = –0.413 (in 1976) to 0.275 ºC (in 1998). The long-term mean of <AMO> (J–N) is –0.008 ºC, having *sd* = 0.223 ºC and range = –0.465 (in 1974) to 0.450 ºC (in 1998). Prior to the mid-1960s and subsequent to the mid-1990s, the 10-yma trend lines for <AMO> (D–M) and (J–N) are reflective of the warm (positive) phase, while between the mid-1960s and the mid-1990s, the 10-yma trend lines are reflective of the cold (negative) phase.

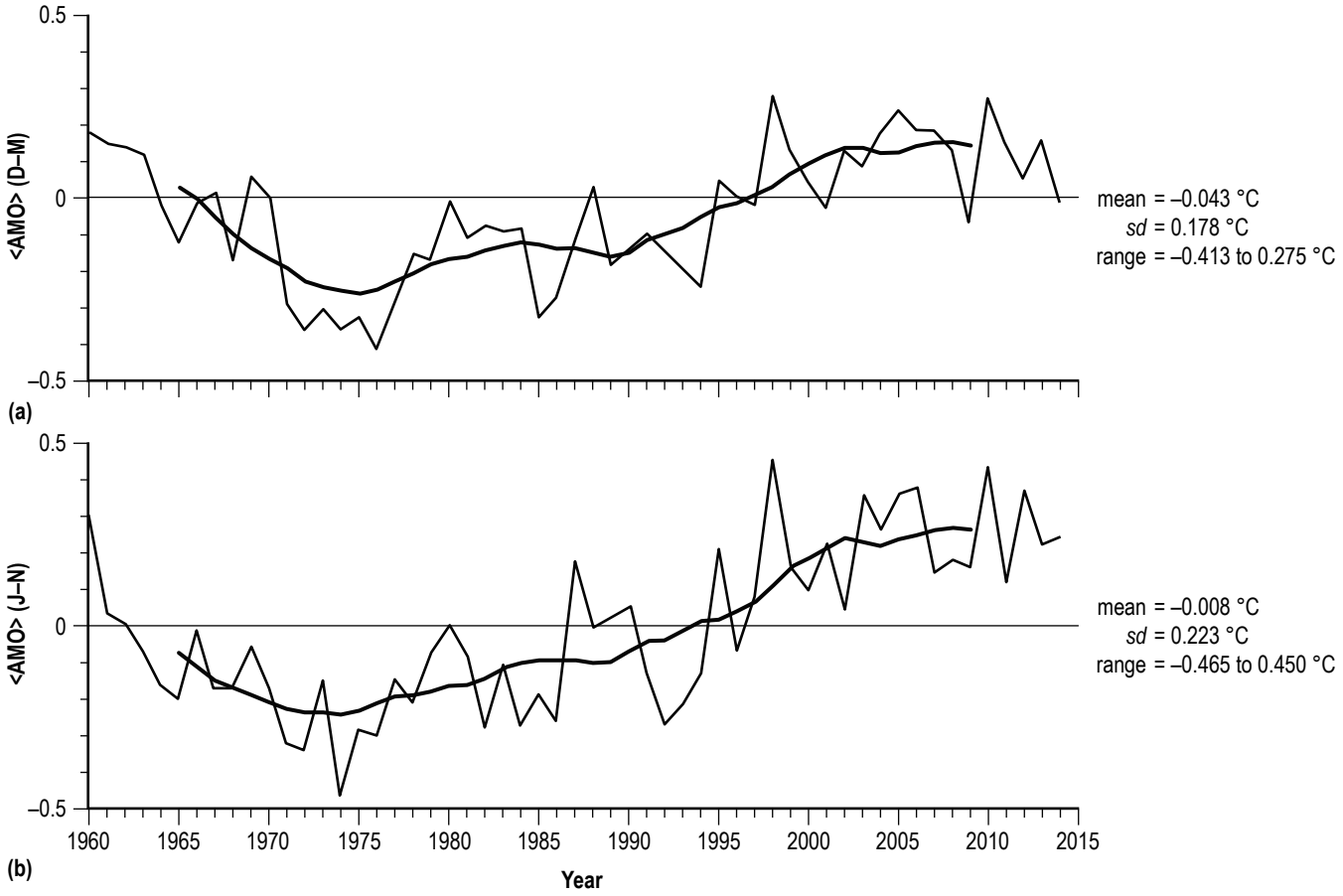


Figure 14. Annual and 10-yma variation of 6-month averages of <AMO> for (a) D–M and (b) J–N.

Figure 15 shows the scatterplot of <AMO> (J–N) versus <AMO> (D–M). Unlike <ONI>, the AMO 6-month average value prior to the hurricane season is found to be a good predictor for the AMO 6-month average value during the hurricane season. The inferred linear regression is $y = 0.035 + 0.995x$, where y is <AMO> (J–N) and x is <AMO> (D–M). The inferred regression has $r = 0.791$, $r^2 = 0.625$, $se = 0.138$ ºC, and confidence level (cl) >99.9%. Now, the <AMO> (D–M) value is known to be –0.001 ºC, inferring that the <AMO> (J–N) value is expected to be about 0.034 ± 0.138 ºC (i.e., the ±1 *se* prediction interval). Hence, the <AMO> during the hurricane season is expected to be of positive value, but could possibly turn out to be of negative value. (<AMO> (J–N) = 0.209 ºC for 2015, a value slightly warmer than the upper bound of the ±1 *se* prediction interval, which is 0.172 ºC.)

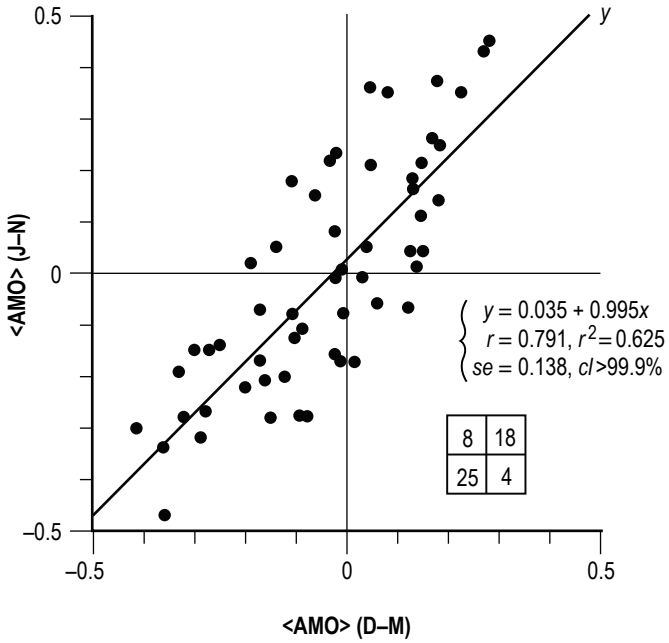


Figure 15. Scatterplot of <AMO> (J–N) versus <AMO> (D–M) using annual parametric values.

Figure 16 depicts the annual and 10-yma variation of the 6-month averages of <AMM> for (a) D–M and (b) J–N. The AMM is part of a broader class of meridional modes that is characterized by an anomalous meridional sea surface temperature across the mean latitude of the intertropical convergence zone. As with ONI and AMO, the AMM fluctuates between warm (positive) and cold (negative) phases. For the weather satellite era, the long-term mean of <AMM> (D–M) is –0.03, having *sd* = 2.34 and range = –5.49 (in 1994) to 3.90 (in 2010). The long-term mean of <AMM> (J–N) is 0.09, having *sd* = 1.97 and range = –4.70 (in 1972) to 4.93 (in 2010). Prior to the mid-1960s and subsequent to the mid-1990s, the 10-yma trend lines for <AMM> (D–M) and (J–N) are reflective of the warm (positive) phase, while between the mid-1960s and the mid-1990s, the 10-yma trend lines are reflective of the cold (negative) phase.

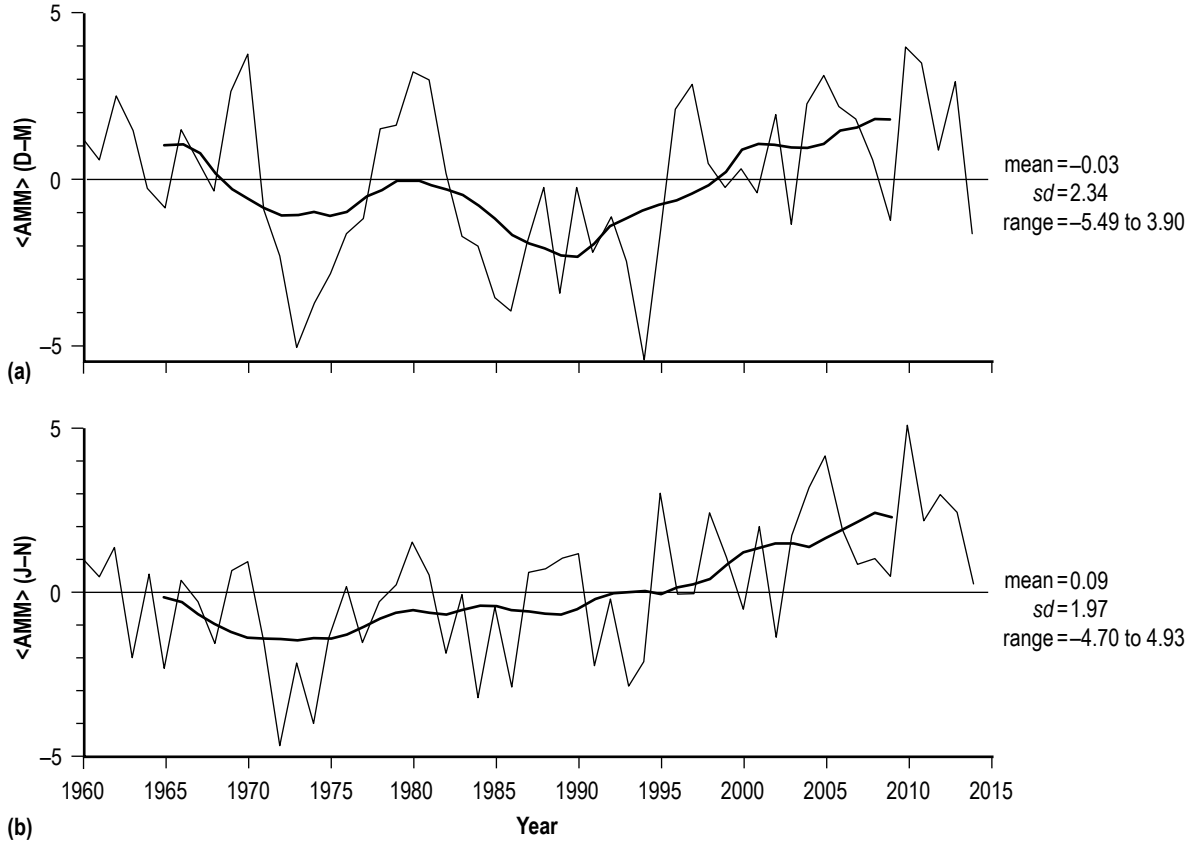


Figure 16. Annual and 10-yma variation of 6-month averages of <AMM> for (a) D–M and (b) J–N.

Figure 17 shows the scatterplot of <AMM> (J–N) versus <AMM> (D–M). As with AMO, a statistically important relationship (albeit somewhat weaker) is found to exist between the 6-month average AMM value preceding the hurricane season and the 6-month average AMM value during the hurricane season. The inferred regression is $y = 0.101 + 0.493x$, where y is the J–N average AMM value and x is the D–M average AMM value. The inferred correlation has $r = 0.587$, $r^2 = 0.344$, $se = 1.607$, and $cl > 99.9\%$. Hence, given the D–M average AMM, one can possibly estimate the value for J–N. Unfortunately, unlike ONI and AMO, the D–M average for AMM has not been published. Only the monthly values for December and January are known, being 1.35 and –0.80, respectively. If the <AMM> (D–N) value turns out to be positive, then one probably would expect the <AMM> (J–N) value to be positive. However, if the <AMM> (D–M) value happens to turn out to be negative, then one would not be able to discern whether <AMM> (J–N) will be positive or negative, since the likelihood for either phase is the same.

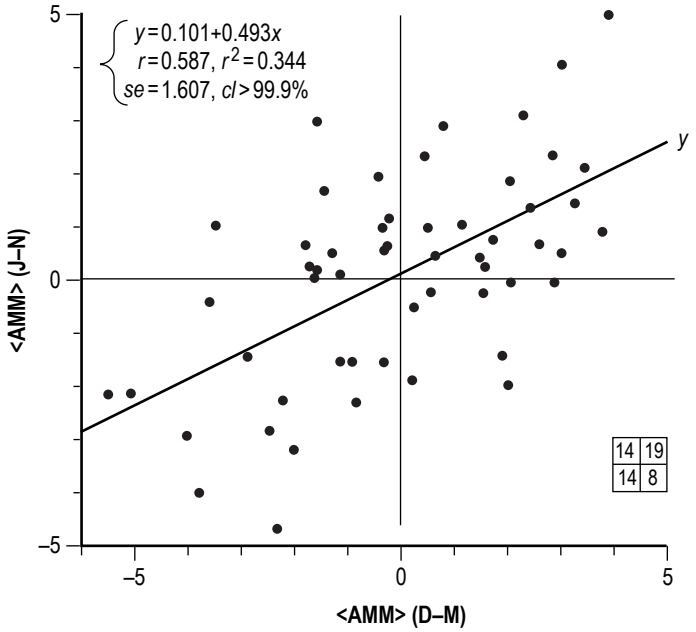


Figure 17. Scatterplot of <AMM> (J–N) versus <AMM> (D–M) using annual parametric values.

Figure 18 displays the annual and 10-yma variation of the 6-month averages of <GLOTI> for (a) D–M and (b) J–N. During the weather satellite era, both <GLOTI> (D–M) and (J–N) averages have been steadily increasing since the late 1960s-early 1970s. The long-term mean for <GLOTI> (D–M) is 0.27 ºC, having *sd* = 0.26 ºC and range –0.16 (in 1964) to 0.73 ºC (in 2010). For <GLOTI> (J–N), its mean is 0.25 ºC, having *sd* = 0.26 ºC and range –0.19 ºC (in 1964) to 0.68 ºC (in 2005 and 2014). (Note: GLOTI monthly values change frequently; the values used in this study were those listed as of April 2015. Values published in December 2015 are found to be somewhat higher. As an example, based on the April 2015 listing, the 2001 value of <GLOTI> (D–M) = 0.46 ºC. Using the more recent December 2015 listing, the 2001 value of <GLOTI> (D–M) = 0.48 ºC. Similarly, the monthly values for December 2014 through February 2015 increased from 0.64, 0.75, and 0.79 ºC to 0.78, 0.81, and 0.87 ºC, respectively. Based on the December 2015 listing, the 2015 <GLOTI> (D–M) = 0.81 ºC, a value that is the highest ever recorded.)

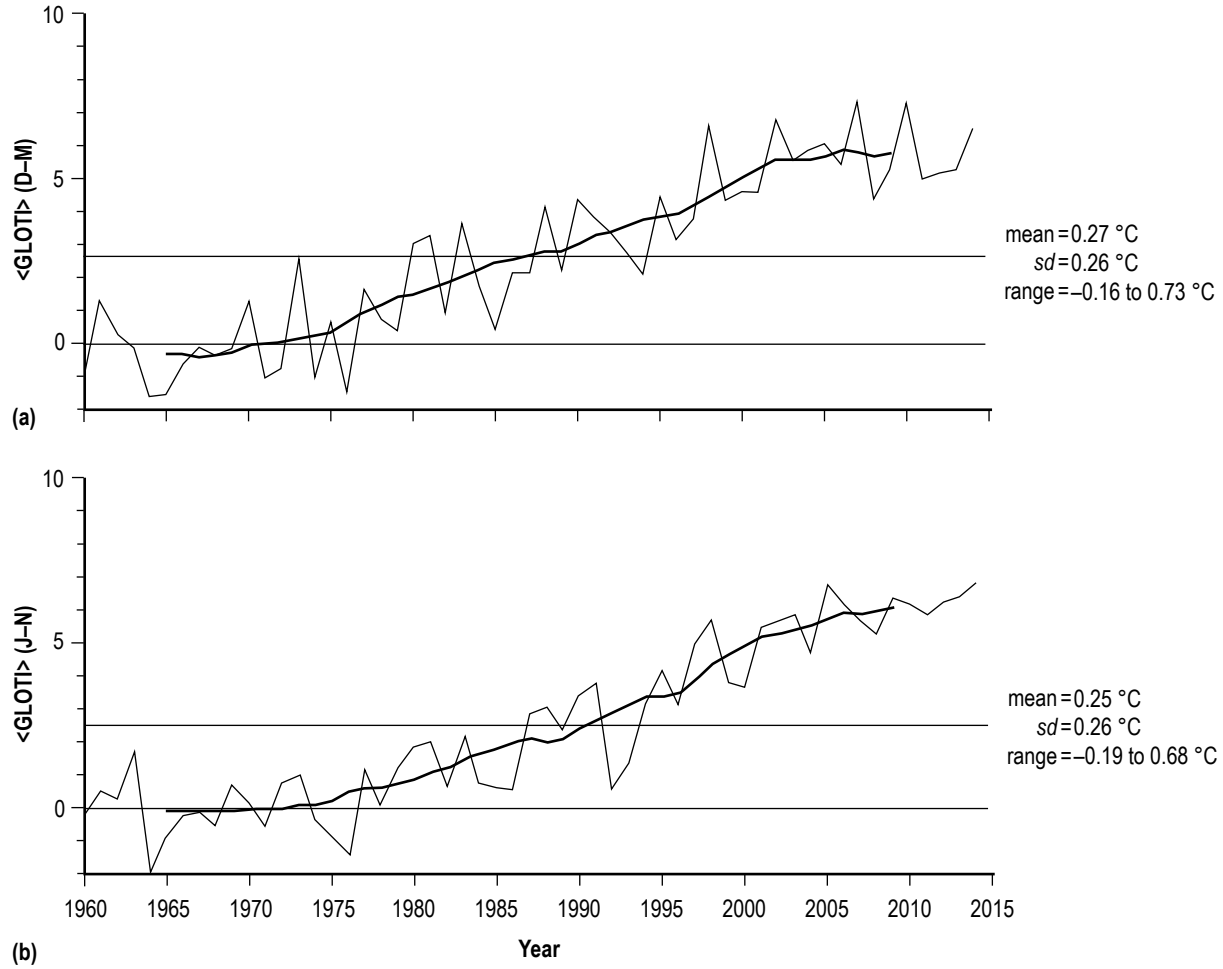


Figure 18. Annual and 10-yma variation of 6-month averages of <GLOTI> for (a) D–M and (b) J–N.

Figure 19 shows the scatterplot of <GLOTI> (J–N) versus <GLOTI> (D–M). A very strong, preferential linear relationship is found to exist between the two parameters, being $y = 0.006 + 0.919x$, having $r = 0.924$, $r^2 = 0.854$, $se = 0.099$, and $cl \gg 99.9\%$. Given <GLOTI> (D–M) = 0.81 ºC (see above), one determines the ±1 *se* prediction interval for <GLOTI> (J–N) to be 0.75 ± 0.10 ºC, which, if true, will be a record high value. (<GLOTI> (J–N) = 0.87 ºC for 2015, a value warmer than the upper bound of the ±1 *se* prediction interval and the highest ever recorded.)

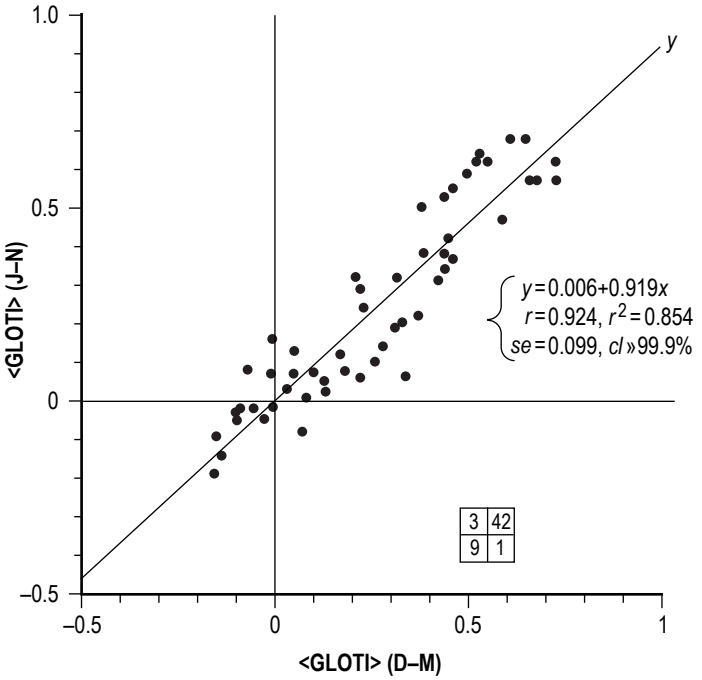


Figure 19. Scatterplot of <GLOTI> (J–N) versus <GLOTI> (D–M) using annual parametric values.

Figure 20 depicts the annual and 10-yma variation of the 6-month averages of <QBO> for (a) D–M and (b) J–N. The QBO refers to the quasi-periodic oscillation of the 30-mb equatorial zonal winds (in units of m s^{-1}) in the tropical stratosphere, having a mean period of about 28 months (ranging between 20 and 36 months), discovered in the 1950s. The winds alternate between easterlies (generally, the stronger winds, numerically identified as those of negative value) and westerlies (generally, weaker winds, but longer lasting at higher levels and shorter lasting at lower levels and identified numerically as those of positive value). The winds first develop at the top of the stratosphere, propagating slowly downwards at the rate of about 1 km per month until they dissipate at the tropical tropopause. For the weather satellite era, <QBO> (D–M) averages –1.46 m s^{-1}, having *sd* = 9.06 m s^{-1} and range = –19.68 (in 2010) to 11.75 m s^{-1} (in 1983), and <QBO> (J–N) averages –5.39 m s^{-1}, having *sd* = 12.73 m s^{-1} and range = –26.41 (in 2007) to 13.26 m s^{-1} (in 2013).

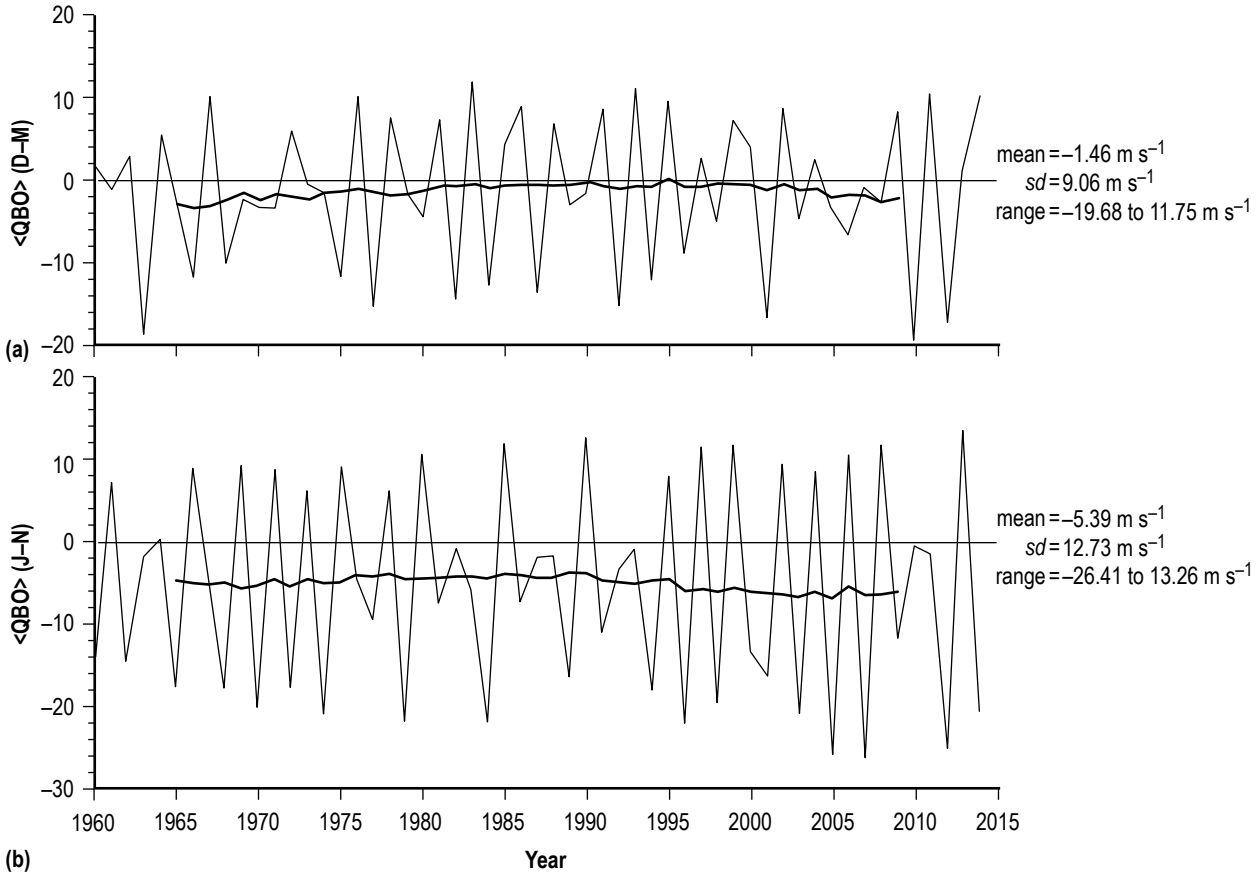


Figure 20. Annual and 10-yma variation of 6-month averages of <QBO> for (a) D–M and (b) J–N.

Figure 21 shows the scatterplot of <QBO> (J–N) versus <QBO> (D–M). Plainly, no statistically important linear relationship can be discerned between the two parameters. The <QBO> (D–M) value for 2015 is known to be –24.26 m s^{-1}, which is of record value for the weather satellite era. The QBO values for June and July 2015 are also known to be 2.18 and 7.45 m s^{-1}, respectively. So, while more negative (easterly) values have been seen for <QBO> (J–N) when <QBO> (D–M) has been negative (easterly, 21 of 31years), the 2015 <QBO> (J–N) appears likely to be positive (westerly). (<QBO> (J–N) = 9.81 m s^{-1} for 2015.)

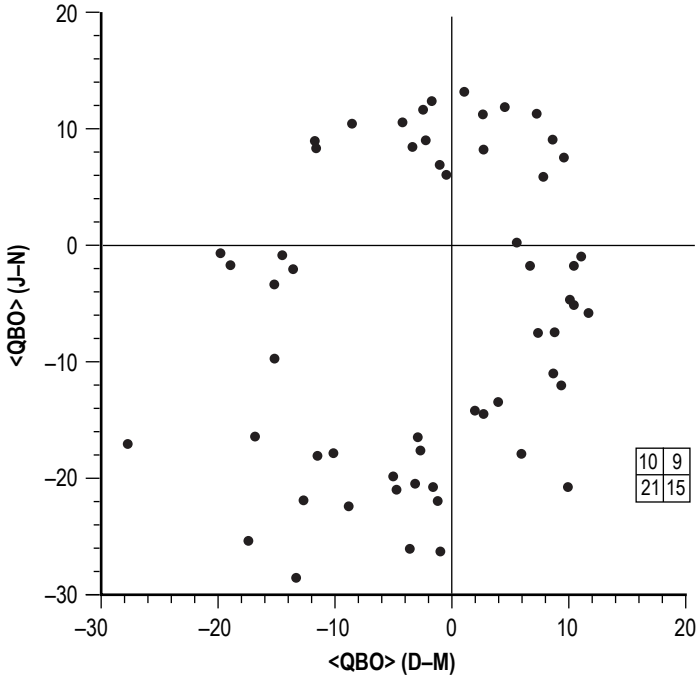


Figure 21. Scatterplot of <QBO> (J–N) versus <QBO> (D–M) using annual parametric values.

2.3 Associational Aspects

In this subsection, scatterplots of selected tropical cyclone seasonal parameters against the seasonal climatic factors are shown, using the trend line values (i.e., the 10-yma parametric values). Computed for most of the scatterplots is the probability due to chance based on the Fisher's exact test for the observed 2×2 contingency tables determined using the median parametric values (the vertical and horizontal lines), or those more suggestive of a departure from independence. Also shown in each scatterplot is the position of the 10-yma parametric values for the year 2009. Tables 8–10 give the first-difference parametric values, which should prove useful for estimating the likely 10-yma parametric values for 2010 (which in turn can provide a crude estimate for the parametric value expected for the current season).

Table 8. Summary of first differences of the 10-yma North Atlantic basin seasonal counts and parametric means.

Year	FSD	LSD	LOS	NTC	NH	NMH	NUSLFH	<PWS>	<LP>	Genesis Loc.		Sum PDI	<PDI>	Sum ACE	<ACE>	Sum NSD	<NSD>	Sum NHD	Sum NMHD	NTCA (%)
										<NLAT>	<WLONG>									
1965	–3	2	5	0.2	–0.1	–0.3	–	–1.8	2.1	0.4	0.5	–10.1	–1.2	–7.8	–1.0	–0.41	–0.15	–1.52	–1.61	–8.1
1966	–5	2	7	0.2	–0.1	–0.3	0.2	–1.9	2.2	0.7	0.9	–6.9	–0.8	–5.4	–0.7	–0.02	–0.08	–1.17	–1.20	–6.9
1967	–6	–	7	0.1	–0.1	–0.1	–	–1.2	1.1	0.7	0.7	–3.5	–0.4	–3.5	–0.4	–0.24	–0.05	–1.58	–0.36	–3.4
1968	–1	–1	–2	–0.1	–0.3	–0.3	–0.2	–1.3	1.4	0.3	0.5	–8.4	–0.8	–8.6	–0.8	–2.11	–0.16	–2.77	–0.86	–8.2
1969	2	1	–	0.1	–	–0.1	–0.2	–0.4	1.1	0.3	0.3	–5.9	–1.6	–5.5	–0.7	–1.10	–0.17	–1.79	–0.79	–4.8
1970	–	2	2	0.1	0.1	0.1	–	0.2	–0.2	0.5	0.3	–3.4	–0.6	–3.5	–0.5	–0.37	–0.11	–1.19	–0.74	–2.3
1971	–1	–2	–1	–0.2	–0.1	–0.1	–0.1	–0.2	0.2	0.6	1.4	–6.6	–0.7	–7.9	–0.8	–2.87	–0.29	–2.31	–0.60	–5.5
1972	3	–	–3	0.1	–0.1	0.1	–	0.2	0.4	0.2	0.7	–3.0	–0.4	–4.0	–0.5	–1.83	–0.26	–1.39	–0.05	–1.1
1973	1	–1	–2	–0.3	–0.3	–	–	–	–0.1	–0.3	–0.4	–1.4	0.1	–2.8	–	–1.93	–0.03	–0.82	0.14	–2.1
1974	2	–	–2	–0.4	–0.1	–0.2	–	0.4	–0.6	–0.2	–1.1	3.4	1.6	1.8	0.6	–0.68	0.13	0.66	0.27	–0.6
1975	1	2	1	–	0.3	0.1	–0.1	0.8	–0.6	–0.2	–1.4	6.0	–0.1	5.7	0.5	1.81	0.17	1.26	0.45	4.1
1976	–3	–2	–	–0.1	–	0.2	–0.2	0.5	–0.6	–0.5	–0.2	0.5	–0.3	–0.1	–	–0.40	–0.03	–0.32	0.20	0.8
1977	3	–3	–5	–0.3	–0.1	–	–	0.5	–0.3	–0.1	0.7	–0.8	–	–1.7	–0.5	–1.86	–0.13	–0.36	0.07	–1.0
1978	5	2	–2	–0.1	–	–	–	–0.1	–	0.3	0.3	–0.9	–0.1	–0.7	0.4	–0.20	–0.02	–0.15	–0.18	–1.3
1979	3	3	–1	0.2	0.1	–0.1	0.3	–0.6	0.2	–0.1	0.2	0.5	–0.1	1.4	–	1.29	0.03	0.25	–0.09	0.6
1980	2	–	–1	–0.1	–0.1	–0.1	0.3	–0.4	0.9	–0.1	0.7	–1.3	–0.1	–1.8	–0.1	–1.09	–0.08	0.31	0.04	–1.7
1981	–	1	1	–0.1	–0.2	–0.1	–	–1.1	1.0	–0.5	–0.9	–1.9	–0.1	–2.0	–0.1	–0.20	0.08	–0.88	–0.07	–2.5
1982	–1	1	1	0.1	–0.1	0.1	0.1	–0.8	–	–0.6	–1.1	2.2	0.1	2.5	0.2	1.44	0.16	0.25	0.25	1.7
1983	1	4	3	0.1	0.1	–	–	0.4	–0.4	–0.2	–0.4	4.1	0.3	4.2	0.2	0.36	0.05	0.89	0.47	3.1
1984	–1	–	–	0.3	–	–	–	–0.8	0.6	–0.3	–0.4	–2.2	–0.4	–0.5	–0.2	2.46	0.03	–0.07	–0.11	–0.2
1985	3	–3	–5	–0.1	–0.2	–0.1	–	–1.2	0.5	–	–	–6.3	–0.6	–5.9	–0.6	–1.57	–0.15	–1.29	–0.44	–4.3
1986	–	–	–	–0.1	–0.1	–0.1	0.1	0.2	–0.5	0.3	–0.4	–0.4	0.2	–1.0	0.1	–1.00	0.01	–0.21	–0.01	–1.3
1987	–4	1	6	0.2	0.2	–	–	–0.1	–0.2	–0.2	–1.3	2.9	0.4	3.3	0.3	1.86	0.14	–0.19	0.14	2.5
1988	–6	–2	3	–0.1	–0.1	–	–	–0.5	0.3	–0.8	–0.7	–1.0	–0.1	–1.5	–0.1	–0.95	–0.02	–0.24	–0.02	–1.2
1989	–4	–3	1	0.1	0.1	–	–0.3	0.1	–0.2	–0.6	–0.5	3.9	0.1	4.3	0.2	1.78	0.04	1.45	0.26	3.6
1990	–2	–1	1	0.8	0.5	0.4	–0.2	0.5	–1.1	–0.8	–0.8	11.6	0.5	13.5	0.5	6.28	0.20	3.73	1.03	13.5
1991	–3	1	3	0.4	0.2	0.3	–	0.5	–1.1	–	0.3	6.3	0.4	6.8	0.3	2.42	0.03	2.00	0.73	8.2
1992	–3	–	5	0.1	0.3	–	0.1	0.3	–0.2	0.3	0.2	3.8	0.3	4.3	0.3	1.67	0.04	1.63	0.10	3.0
1993	–2	–	1	0.2	0.3	0.2	0.1	1.2	–0.8	–0.1	0.1	5.1	0.3	6.0	0.3	2.69	0.14	1.79	0.23	5.1

Table 8. Summary of first differences of the 10-yma North Atlantic basin seasonal counts and parametric means (Continued).

Year	FSD	LSD	LOS	NTC	NH	NMH	NUSLFH	<PWS>	<LP>	Genesis Loc.		Sum PDI	<PDI>	Sum ACE	<ACE>	Sum NSD	<NSD>	Sum NHD	Sum NMHD	NTCA (%)
										<NLAT>	<WLONG>									
1994	–	–	–	0.1	–	0.2	–	0.8	–0.9	–	0.8	3.3	0.2	3.2	0.2	0.57	0.01	0.73	0.41	4.2
1995	–1	2	3	0.4	0.3	0.2	–	0.6	–0.4	–0.1	0.5	4.1	0.1	4.8	0.2	2.14	0.06	1.16	0.35	5.5
1996	3	1	–2	0.6	0.2	0.2	–0.1	–0.5	0.5	–0.3	0.6	1.8	–0.1	3.2	–0.2	3.04	0.02	0.56	0.13	4.7
1997	1	3	2	0.6	0.2	0.1	0.1	–0.3	0.1	–	0.6	6.0	0.1	6.4	0.1	3.97	0.06	0.84	0.77	7.1
1998	–1	5	6	0.8	0.4	0.4	0.3	1.3	–1.3	0.2	–0.1	16.9	0.9	16.6	–0.1	6.40	0.21	3.05	1.91	16.2
1999	2	4	2	0.9	0.5	0.4	0.5	0.9	–1.0	0.2	–	11.9	0.4	10.9	0.7	3.72	0.01	1.32	1.42	12.6
2000	–1	–	1	0.3	–	–0.1	0.1	–0.5	0.6	0.5	–0.1	–2.0	–0.3	–3.2	–0.4	–0.27	–0.07	–1.77	–0.25	–2.3
2001	–1	–	1	0.2	–	–0.1	–0.1	–0.1	0.4	–	–0.5	–2.6	–0.2	–2.8	–0.3	–0.33	–0.04	–1.05	–0.37	–2.9
2002	–4	2	6	0.4	–	0.1	–	0.1	–	–0.2	0.1	–0.1	–0.2	–0.1	–0.2	0.52	–0.09	–0.80	0.10	2.0
2003	–	–2	–2	–	–0.3	–	–0.1	–1.6	1.3	0.1	–0.3	–8.1	–0.6	–5.0	–0.6	–2.32	–0.20	–2.35	–0.61	–5.9
2004	1	–	–1	–	–0.1	–0.1	–0.2	–0.8	1.1	–0.1	–0.8	–3.3	–0.4	–3.8	–0.4	3.53	0.11	–1.13	–0.22	–0.7
2005	–1	–1	–	0.4	0.1	0.1	0.1	–	–0.1	–0.3	–0.1	2.9	–	3.2	–	10.09	0.28	0.32	0.31	5.3
2006	–1	–	2	0.6	0.2	–	–	–0.4	0.1	–0.2	–0.5	2.5	–	4.3	0.1	3.37	0.04	0.76	–0.13	2.4
2007	–1	1	1	0.2	0.1	–0.1	–0.1	–0.7	0.5	–0.3	–0.9	–5.3	–0.4	–3.4	–0.4	–0.22	–0.10	–0.73	–0.97	–4.7
2008	1	–2	–3	–0.4	–0.4	–0.4	–0.3	–1.2	1.1	–	0.2	–15.3	–0.8	–14.7	–0.7	–5.28	–0.21	–2.76	–1.76	–13.9
mean	–0.5	0.4	0.9	0.1	–	–	–	–0.2	0.2	–	–0.1	–	–0.1	0.2	–0.1	0.78	–0.01	–0.13	–0.04	0.4
sd	2.5	1.9	3.0	0.3	0.2	0.2	0.2	0.8	0.8	0.4	0.7	6.0	0.5	5.9	0.4	2.74	0.13	1.46	0.69	5.8

Table 9. Summary of first difference of the 10-yma largest individual storm parametric values.

Year	SISPWS	SISLP	SISPDI	SISACE	SISNSD	SISNHD	SISNMHD	*N*(4/5)
1965	–2.0	1.8	–4.7	–3.2	–	0.01	–0.81	–0.25
1966	–1.0	2.4	–1.1	–0.4	0.43	0.41	–0.40	–0.15
1967	–1.7	2.4	–2.0	–1.8	–0.14	–0.50	–0.33	–0.05
1968	–1.5	0.5	–1.3	–2.4	–0.44	–0.65	–0.36	–0.20
1969	–1.0	–0.8	–2.2	–1.9	–0.42	–0.41	–0.38	–0.15
1970	–2.0	1.3	–3.1	–2.5	–0.40	–0.39	–0.60	–0.05
1971	–0.8	1.6	–3.3	–3.0	–0.71	–0.59	–0.51	–0.05
1972	2.8	–0.8	–1.2	–1.3	–0.45	–0.38	–0.10	0.10
1973	1.5	0.1	1.7	1.2	–0.10	–0.09	0.19	0.15
1974	2.0	–1.4	4.1	2.9	0.13	0.41	0.36	0.10
1975	1.5	–2.1	2.4	1.1	–0.27	–0.16	0.33	0.05
1976	–	–1.2	–0.3	–0.9	–0.75	–0.56	0.08	0.05
1977	1.2	–1.2	0.1	–0.1	–0.35	–0.03	0.07	0.05
1978	–0.7	1.1	–0.8	–0.6	–0.18	–0.06	–0.10	–
1979	–0.5	0.1	–0.5	–0.3	0.05	–0.03	–0.09	–
1980	–0.5	0.1	–0.4	–0.5	–0.23	–0.22	–0.03	–
1981	–2.8	2.7	–0.7	–0.6	0.16	–0.22	–0.06	–0.05
1982	–	–1.3	0.7	0.6	0.56	0.13	0.08	–
1983	1.5	–3.3	0.7	0.7	0.13	0.23	0.15	0.05
1984	–3.5	2.3	–2.7	–1.6	–0.14	–0.18	–0.23	–0.05
1985	–3.0	2.8	–2.8	–1.8	–0.25	–0.32	–0.30	–0.05
1986	1.8	–1.4	0.4	0.1	0.15	–0.10	0.09	–
1987	1.7	–1.5	1.4	1.2	0.60	0.30	0.14	–
1988	–1.0	1.0	0.3	0.4	0.27	0.13	–0.02	–0.05
1989	–0.7	1.1	1.6	1.2	0.20	0.14	0.29	0.05
1990	2.0	–2.4	3.9	3.1	0.45	0.44	0.69	0.20
1991	1.7	–2.9	2.6	2.2	0.20	0.44	0.50	0.10
1992	–0.2	0.3	1.0	1.1	0.04	0.38	0.05	–0.05
1993	–0.5	1.0	0.1	0.3	0.01	0.13	–0.01	0.10
1994	0.5	–0.6	0.4	0.6	0.34	0.19	0.11	0.25
1995	1.2	–1.4	0.6	1.0	0.60	0.28	0.14	0.15
1996	–0.7	0.3	–0.6	–0.4	0.47	0.02	–0.04	0.05
1997	1.0	1.3	2.1	1.8	0.39	0.12	0.27	0.10
1998	4.7	–5.4	6.6	5.0	0.41	0.59	0.87	0.25
1999	4.0	–4.9	3.2	2.2	0.10	0.15	0.33	0.25
2000	0.5	–0.8	–2.3	–1.9	–0.22	–0.33	–0.48	–
2001	1.0	–0.8	–0.8	–0.9	–0.25	–0.13	–0.24	–
2002	0.5	–0.5	0.6	0.5	0.01	–0.09	0.11	0.15
2003	–2.5	2.6	–1.2	–0.8	0.04	–0.19	–0.12	–0.15
2004	–0.2	0.3	–0.1	–0.6	0.49	–0.22	–0.04	–0.10
2005	0.5	–0.6	1.1	0.6	0.78	0.07	0.15	0.10
2006	–1.5	0.3	0.4	0.8	0.34	0.28	–0.04	–0.05
2007	–4.5	3.2	–3.5	–2.3	–0.06	–0.40	–0.47	–0.15
2008	–4.3	4.7	–6.2	–4.8	–0.59	–0.72	–0.74	–0.20
mean	–0.1	–	–0.1	–0.1	0.03	–0.05	–0.03	0.01
sd	2.0	2.1	2.4	1.8	0.37	0.32	0.35	0.12

Table 10. Summary of first difference of the 10-yma climate parametric means.

	<ONI>		<AMO>		<AMM>		<GLOTI>		<QBO>	
Year	D–M	J–N	D–M	J–N	D–M	J–N	D–M	J–N	D–M	J–N
1965	–0.03	–0.08	–0.031	–0.041	0.05	–0.11	–	–	–0.37	–0.24
1966	–0.05	0.05	–0.047	–0.035	–0.31	–0.40	–0.01	–	0.05	–0.09
1967	0.05	–0.03	–0.047	–0.021	–0.59	–0.31	0.01	–	1.10	0.24
1968	–0.04	–0.11	–0.038	–0.019	–0.52	–0.23	0.01	–	0.57	–0.67
1969	–0.11	–0.14	–0.027	–0.020	–0.28	–0.19	0.02	0.01	–0.82	0.27
1970	–0.13	–0.12	–0.030	–0.018	–0.26	0.03	–	–	0.63	0.66
1971	–0.05	0.05	–0.035	–0.013	–0.24	–0.08	0.01	–	–0.17	–0.90
1972	0.08	–	–0.013	–0.001	0.01	0.01	0.01	0.01	–0.38	0.97
1973	–	–0.06	–0.011	–0.003	0.05	0.04	0.01	–	0.94	–0.36
1974	–0.05	0.01	–0.011	0.008	–0.08	0.01	0.01	0.01	–0.01	–
1975	0.03	0.06	0.008	0.020	0.17	0.13	0.03	0.03	0.48	0.75
1976	0.05	0.01	0.023	0.015	0.32	0.24	0.03	0.01	–0.50	0.06
1977	0.05	0.05	0.024	0.005	0.30	0.25	0.02	–	–0.41	0.26
1978	0.09	0.05	0.025	0.011	0.26	0.15	0.02	0.01	0.07	–0.65
1979	0.03	0.05	0.013	0.014	0.05	0.09	0.01	0.02	0.27	0.10
1980	0.03	0.05	0.006	0.006	–0.15	–0.10	0.02	0.02	0.76	–
1981	0.07	0.05	0.015	0.018	–0.15	–0.05	0.02	0.01	0.01	0.29
1982	0.03	–0.01	0.018	0.027	–0.13	0.15	0.02	0.03	0.03	–0.05
1983	–0.07	–0.08	0.008	0.015	–0.34	0.09	0.02	0.02	–0.12	–0.13
1984	–0.08	–0.02	–0.007	0.007	–0.43	0.02	0.02	0.01	0.05	0.36
1985	0.02	0.07	–0.006	–	–0.43	–0.15	0.01	0.02	0.20	–0.08
1986	0.10	–0.01	–0.003	–0.002	–0.33	–0.04	0.01	0.01	0.02	–0.32
1987	–	–0.04	–0.009	–0.005	–0.11	–0.05	0.01	–0.01	–0.07	0.11
1988	–0.04	0.08	–0.013	0.001	–0.22	–0.09	–	0.01	0.04	0.44
1989	0.11	0.05	0.011	0.028	–0.08	0.22	0.02	0.03	0.33	–0.01
1990	0.06	–0.04	0.032	0.029	0.41	0.32	0.03	0.03	–0.63	–0.95
1991	–0.08	–0.02	0.019	0.004	0.54	0.11	0.01	0.02	–0.07	–0.08
1992	–	0.04	0.016	0.018	0.26	0.05	0.02	0.03	0.23	–0.24
1993	0.07	–0.02	0.028	0.022	0.20	0.08	0.02	0.02	–0.12	0.50
1994	–0.07	–0.09	0.025	0.007	0.18	–0.09	0.01	–	0.80	0.10
1995	–0.11	–0.09	0.013	0.017	0.11	0.13	0.01	0.01	–0.98	–1.56
1996	–0.11	–	0.017	0.033	0.24	0.13	0.02	0.04	–0.07	0.36
1997	–0.05	0.05	0.028	0.044	0.21	0.15	0.03	0.05	0.40	–0.38
1998	0.01	–	0.035	0.049	–	0.49	0.03	0.03	–0.10	0.32
1999	–0.01	0.03	0.030	0.027	0.62	0.32	0.03	0.02	0.03	–0.37
2000	–0.01	0.06	0.019	0.029	0.23	0.14	0.02	0.03	–0.55	–0.06
2001	0.02	–0.09	0.019	0.025	–0.06	0.14	0.03	0.01	0.65	–0.25
2002	–0.12	–0.10	0.003	–0.011	–0.05	–0.03	–	0.01	–0.80	–0.31
2003	–0.09	0.13	–0.018	–0.014	–0.04	–0.10	–	0.01	0.22	0.39
2004	0.15	0.07	0.001	0.019	0.13	0.25	0.01	0.02	–1.08	–0.53
2005	0.09	–0.05	0.020	0.013	0.38	0.28	0.02	0.02	0.17	1.37
2006	–0.06	–0.05	0.005	0.011	0.14	0.23	–0.01	–	0.05	–0.99
2007	–0.07	–0.06	–0.001	0.009	0.16	0.24	–0.01	0.01	–1.00	–0.01
2008	–0.08	–0.05	–0.006	–0.008	0.02	–0.11	0.01	0.01	0.67	0.25
mean	–0.01	–0.01	0.002	0.007	0.01	0.05	0.01	0.01	0.01	–0.03
sd	0.07	0.06	0.022	0.019	0.28	0.18	0.01	0.01	0.52	0.53

Figure 22 shows the scatterplots of the 10-yma values of FSD versus the 10-yma D–M values of (a) <ONI>, (b) <AMO>, (c) <AMM>, (d) <GLOTI>, and (e) <QBO>. For FSD, all scatterplots are inferred to be statistically important, except the one for FSD versus <QBO> (D–M). The strongest association is the one between FSD and <AMO> (D–M), having $P = 5.5\times10^{-5}$ %. The 10-yma parametric values for 2010, not shown, should lie within the lower-left quadrant for <ONI> and <QBO>, but in the lower-right quadrants for <AMO>, <AMM>, and <GLOTI>. (Note: The comparison here is against the D–M 10-yma parametric values; for the comparisons given hereafter, they will be based on the J–N 10-yma parametric values.)

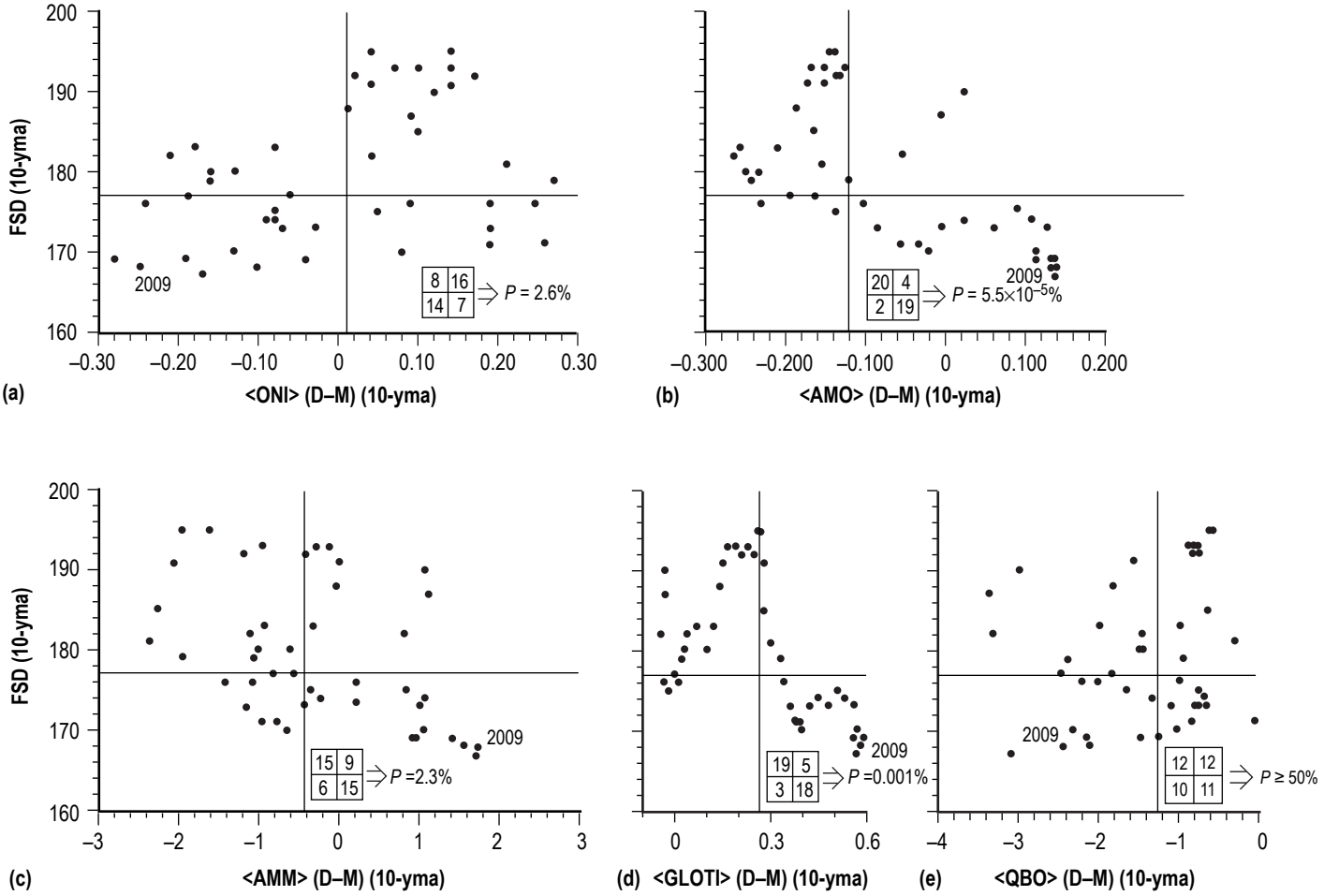


Figure 22. Scatterplots of 10-yma values of FSD versus 10-yma D–M values of (a) <ONI>, (b) <AMO>, (c) <AMM>, (d) <GLOTI>, and (e) <QBO>.

Figure 23 depicts the scatterplots of the 10-yma values of LOS versus the 10-yma J–N values of (a) <ONI>, (b) <AMO>, (c) <AMM>, (d) <GLOTI>, and (e) <QBO>. All scatterplots are inferred to be statistically important, except for the one based on <ONI> (J–N), with the strongest inferred association being the one between LOS and <QBO> (J–N), having $P = 0.006\%$. The 2010 parametric values should lie in the upper-right quadrant for <AMO>, <AMM>, and <GLOTI>, but in the upper-left quadrant for <ONI> and <QBO>.

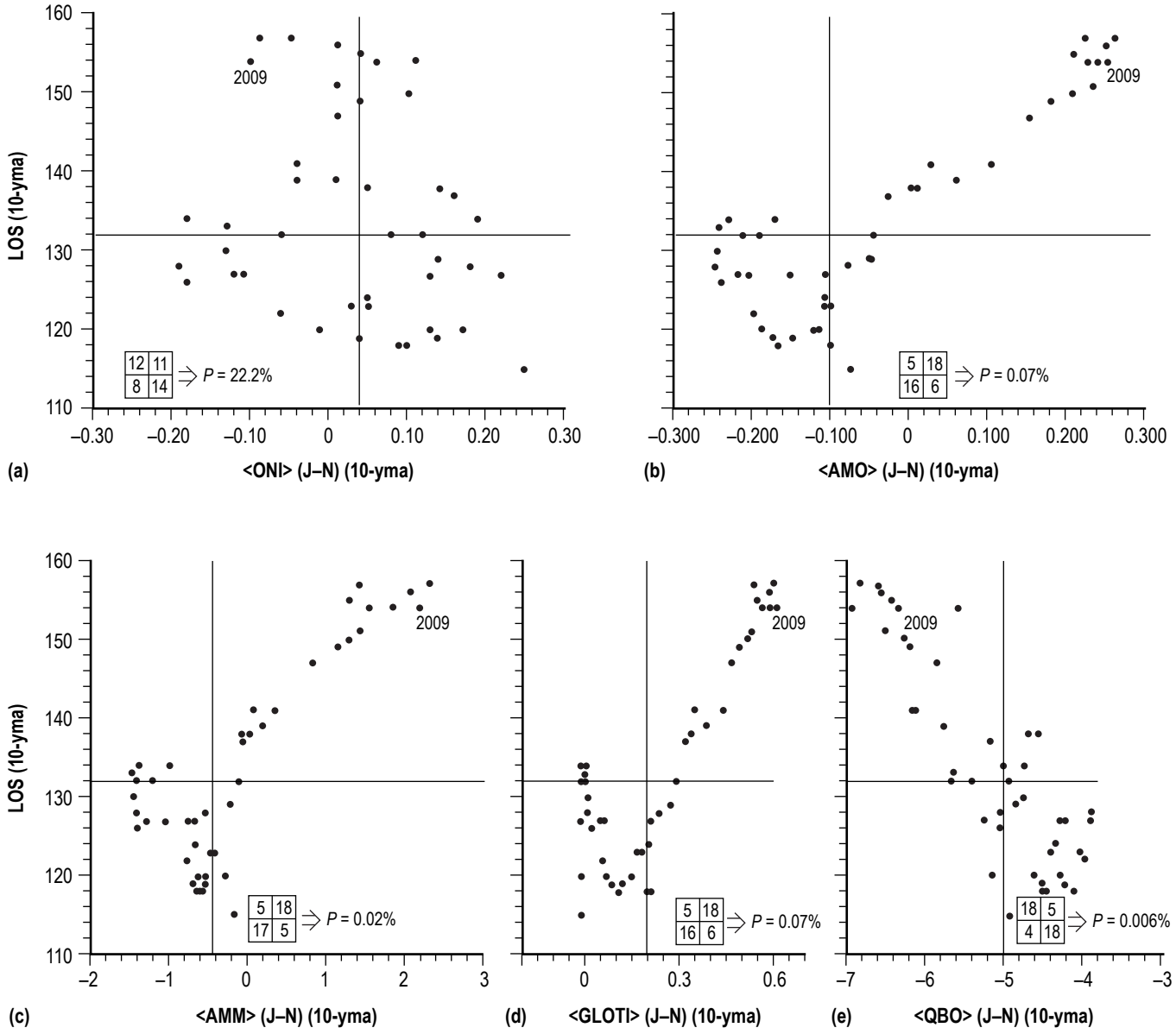


Figure 23. Scatterplots of 10-yma values of LOS versus 10-yma J–N values of (a) <ONI>, (b) <AMO>, (c) <AMM>, (d) <GLOTI>, and (e) <QBO>.

Figure 24 displays the scatterplots of the 10-yma values of NTC versus the 10-yma J–N values of (a) <ONI>, (b) <AMO>, (c) <AMM>, (d) <GLOTI>, and (e) <QBO>. All scatterplots are inferred to be statistically important, except for the one based on <ONI> (J–N), with the strongest inferred association being the one between NTC and <AMO> (J–N) and <AMM> (J–N), each having $P = 0.002\%$. The 2010 parametric values should lie in the upper-right quadrant for <AMO>, <AMM>, and <GLOTI>, but in the upper-left quadrant for <ONI> and <QBO>.

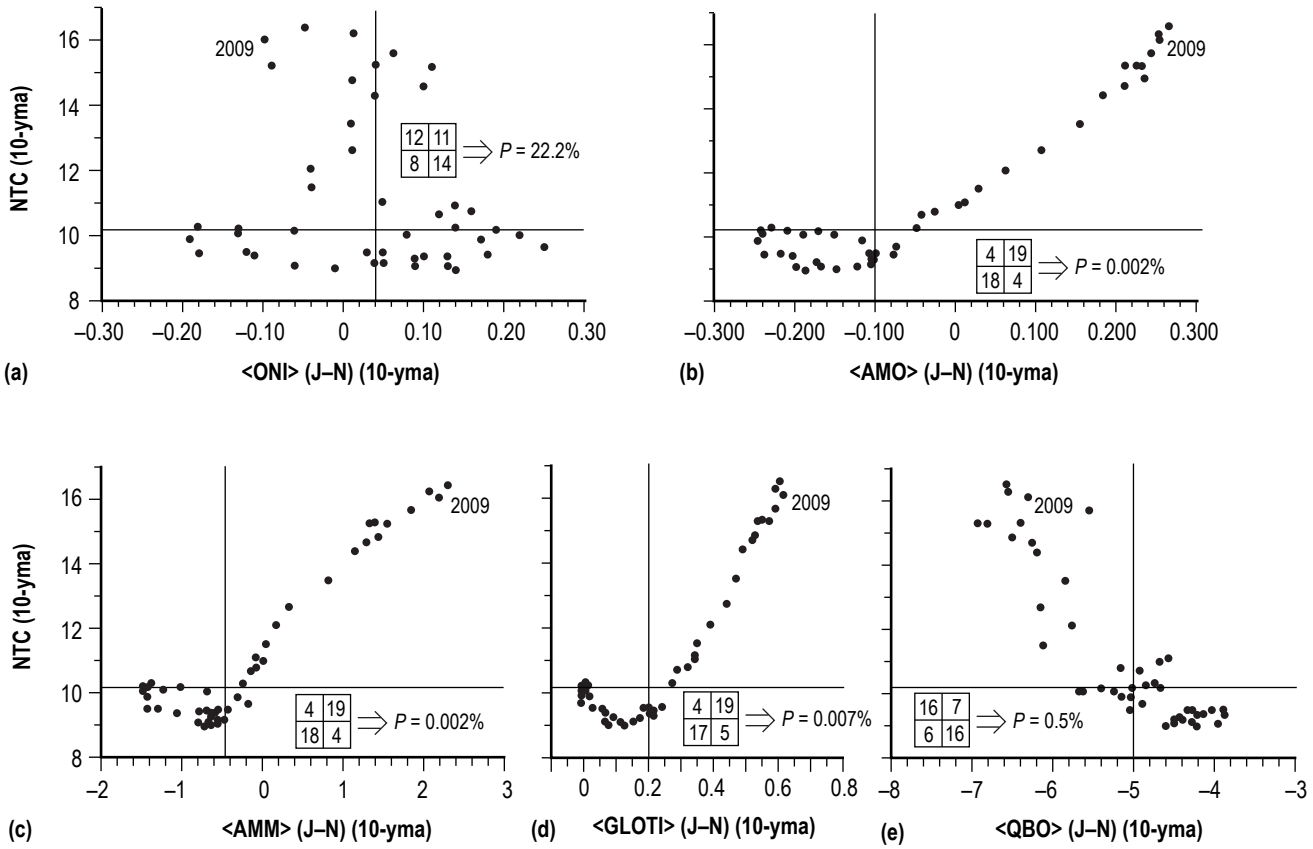


Figure 24. Scatterplots of 10-yma values of NTC versus 10-yma J–N values of (a) <ONI>, (b) <AMO>, (c) <AMM>, (d) <GLOTI>, and (e) <QBO>.

Figure 25 shows the scatterplots of the 10-yma values of NH versus the 10-yma J–N values of (a) <ONI>, (b) <AMO>, (c) <AMM>, (d) <GLOTI>, and (e) <QBO>. All scatterplots are inferred to be statistically important, except for the one based on <ONI> (J–N), with the strongest inferred association being the one between NTC and <AMM> (J–N), having $P = 6.8 \times 10^{-5}$ %. The 2010 parametric values should lie in the upper-right quadrant for <AMO>, <AMM>, and <GLOTI>, but in the upper-left quadrant for <ONI> and <QBO>.

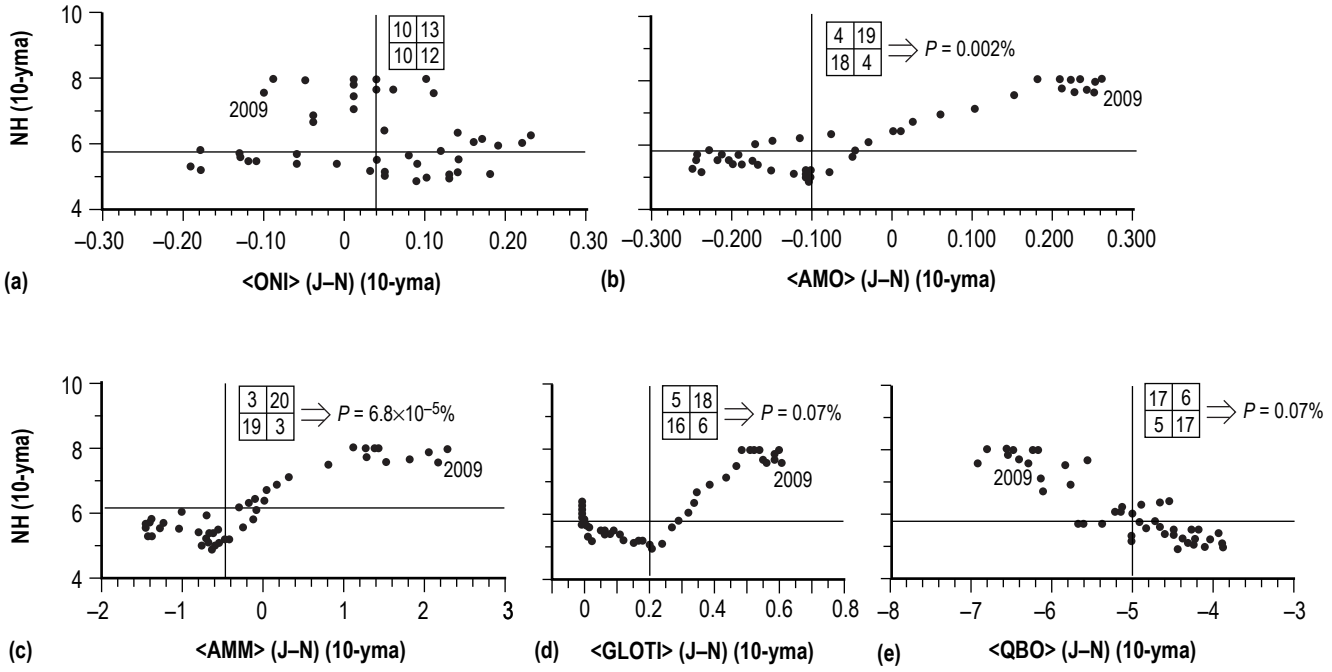


Figure 25. Scatterplots of 10-yma values of NH versus 10-yma J–N values of (a) <ONI>, (b) <AMO>, (c) <AMM>, (d) <GLOTI>, and (e) <QBO>.

Figure 26 depicts the scatterplots of the 10-yma values of NMH versus the 10-yma J–N values of (a) <ONI>, (b) <AMO>, (c) <AMM>, (d) <GLOTI>, and (e) <QBO>. All scatterplots are inferred to be statistically important, except for the one based on <ONI> (J–N), with the strongest inferred association being the one between NMH and <GLOTI> (J–N), having $P = 0.002\%$. The 2010 parametric values should lie in the upper-right quadrant for <AMO>, <AMM>, and <GLOTI>, but in the upper-left quadrant for <ONI> and <QBO>.

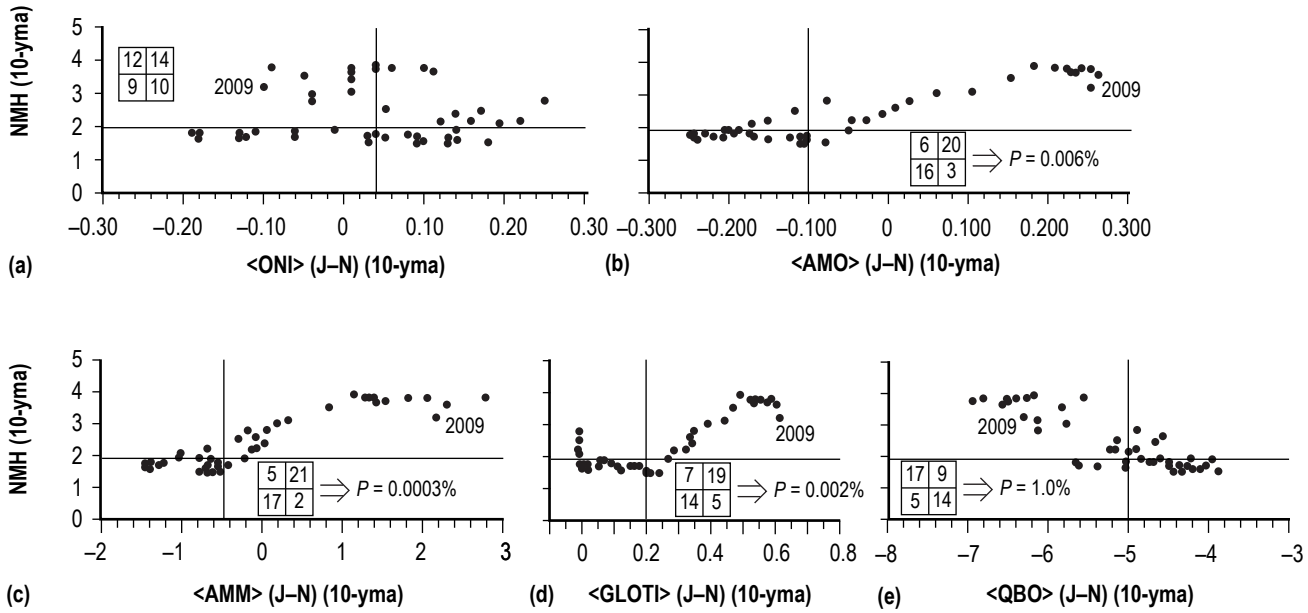


Figure 26. Scatterplots of 10-yma values of NMH versus 10-yma J–N values of (a) <ONI>, (b) <AMO>, (c) <AMM>, (d) <GLOTI>, and (e) <QBO>.

Figure 27 displays the scatterplots of the 10-yma values of <NLAT> versus the 10-yma J–N values of (a) <ONI>, (b) <AMO>, (c) <AMM>, (d) <GLOTI>, and (e) <QBO>. All scatterplots are inferred to be statistically important, except for the one based on <ONI> (J–N), with the strongest inferred association being the one between <NLAT> and <AMO> (J–N), having $P = 1.4\times10^{-7}\%$. The 2010 parametric values should lie in the lower-right quadrant for <AMO>, <AMM>, and <GLOTI>, but in the lower-left quadrant for <ONI> and <QBO>.

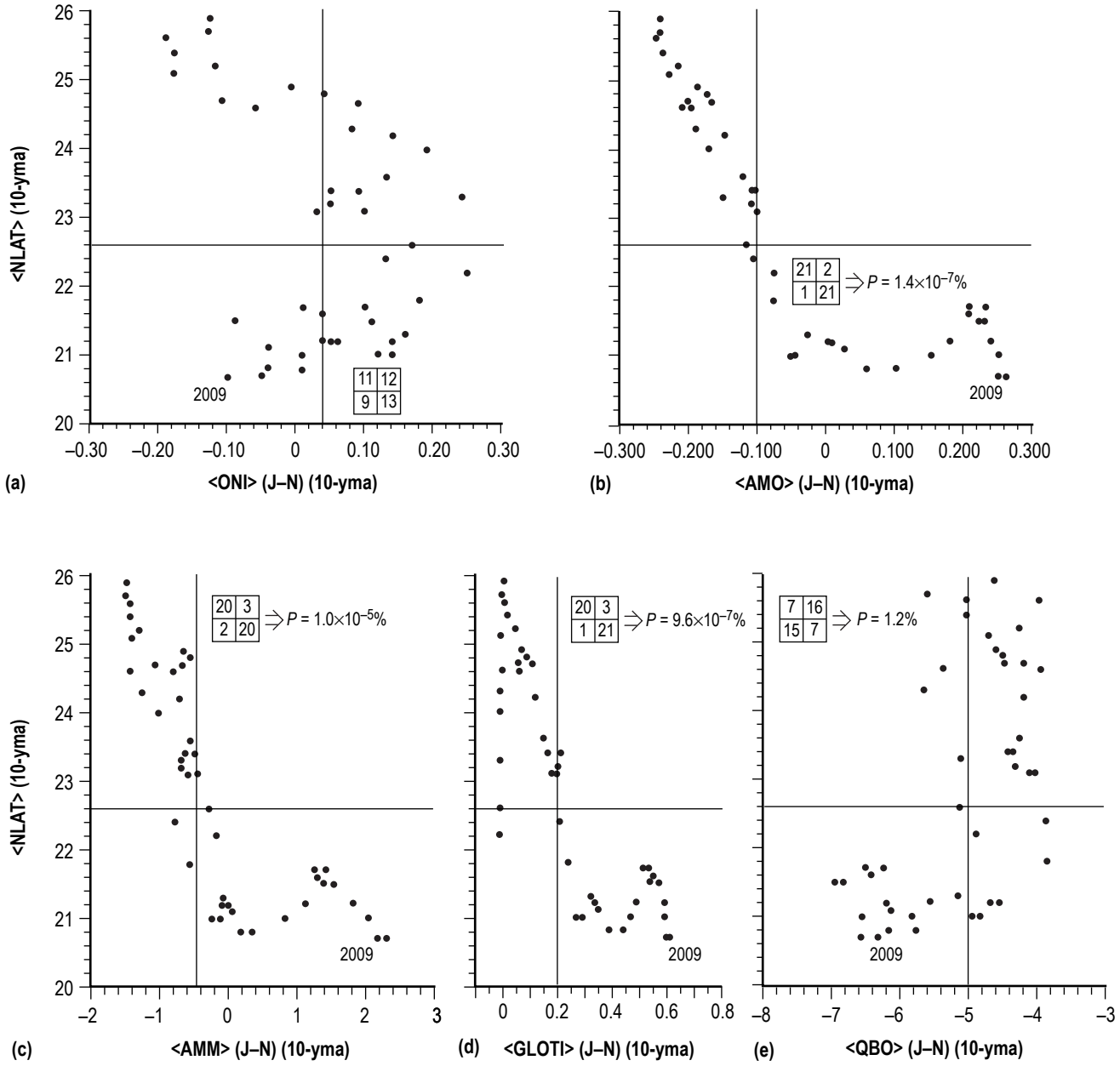


Figure 27. Scatterplots of 10-yma values of <NLAT> versus 10-yma J–N values of (a) <ONI>, (b) <AMO>, (c) <AMM>, (d) <GLOTI>, and (e) <QBO>.

Figure 28 shows the scatterplots of the 10-yma values of <WLONG> versus the 10-yma J–N values of (a) <ONI>, (b) <AMO>, (c) <AMM>, (d) <GLOTI>, and (e) <QBO>. All scatterplots are inferred to be statistically important, except for those based on <ONI> (J–N) and <QBO> (J–N), with the strongest inferred association being the one between <WLONG> and <GLOTI> (J–N), having $P = 2.4\times10^{-4}\%$. The 2010 parametric values should lie in the lower-right quadrant for <AMO>, <AMM>, and <GLOTI>, but in the lower-left quadrant for <ONI> and <QBO>.

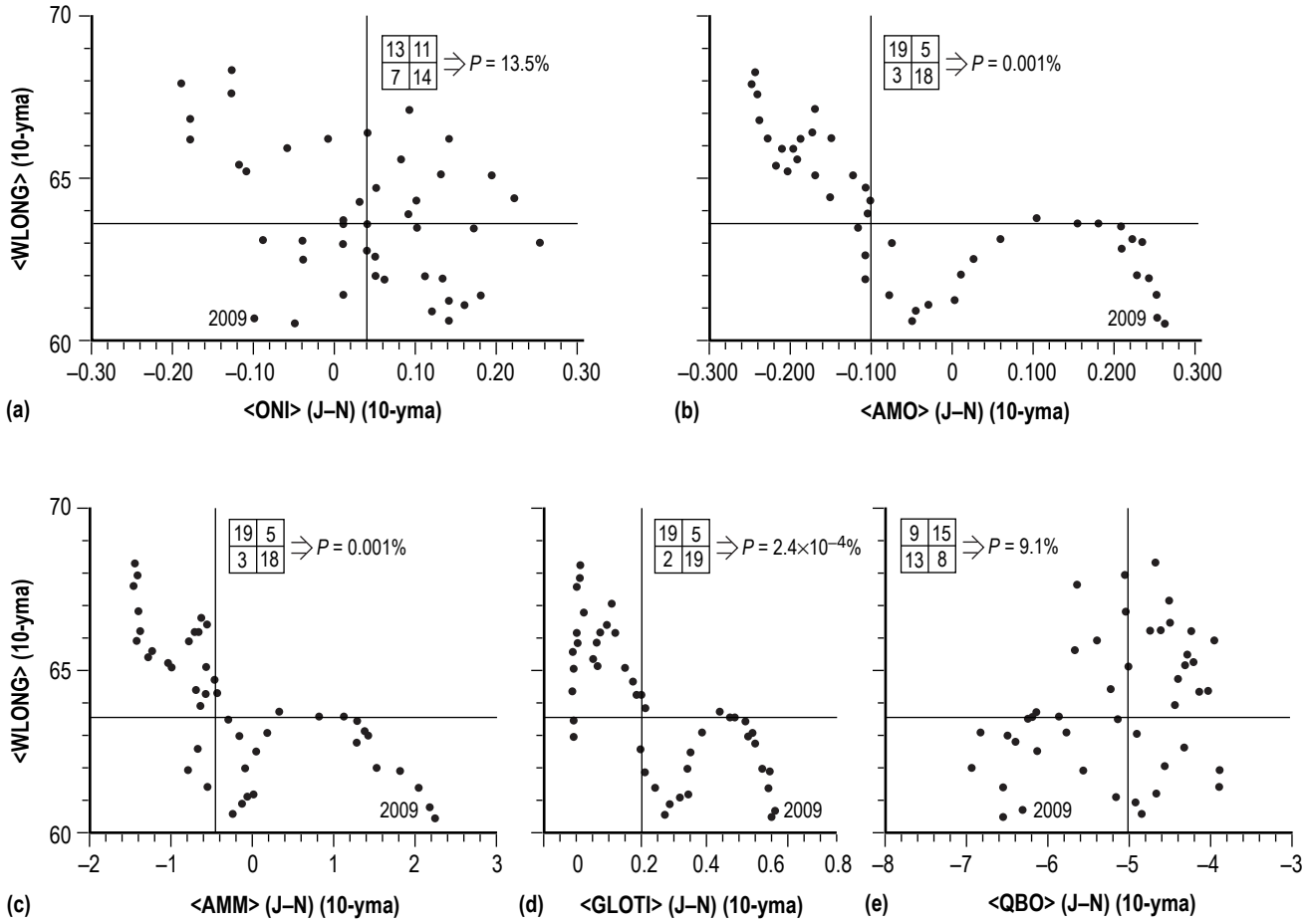


Figure 28. Scatterplots of 10-yma values of <WLONG> versus 10-yma J–N values of (a) <ONI>, (b) <AMO>, (c) <AMM>, (d) <GLOTI>, and (e) <QBO>.

Figure 29 depicts the scatterplots of the 10-yma values of Sum PDI versus the 10-yma J–N values of (a) <ONI>, (b) <AMO>, (c) <AMM>, (d) <GLOTI>, and (e) <QBO>. All scatterplots are inferred to be statistically important, except for the one based on <ONI> (J–N), with the strongest inferred association being the one between Sum PDI and <AMM> (J–N), having $P = 1.0 \times 10^{-5}\%$. The 2010 parametric values should lie in the upper-right quadrant for <AMO>, <AMM>, and <GLOTI>, but in the upper-left quadrant for <ONI> and <QBO>.

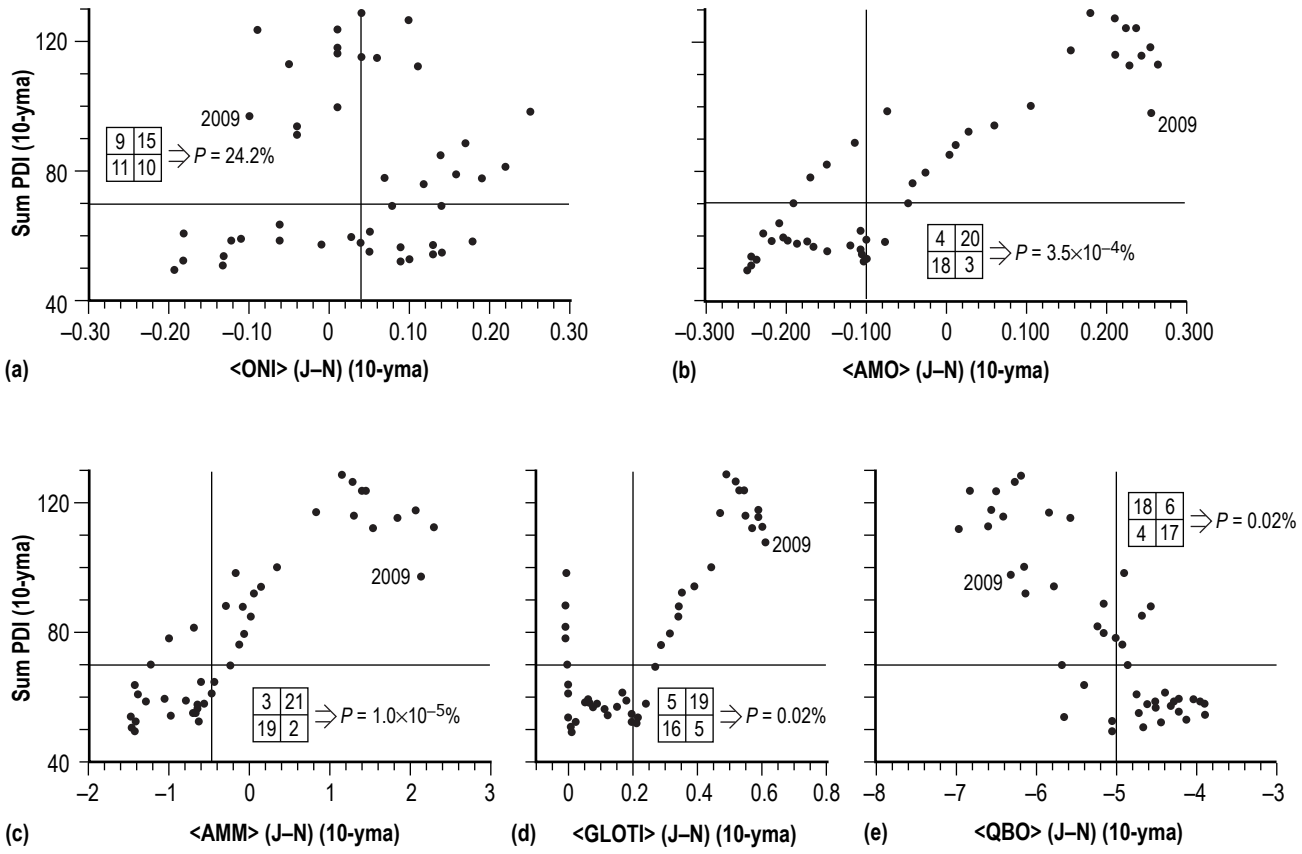


Figure 29. Scatterplots of 10-yma values of Sum PDI versus 10-yma J–N values of (a) <ONI>, (b) <AMO>, (c) <AMM>, (d) <GLOTI>, and (e) <QBO>.

Figure 30 displays the scatterplots of the 10-yma values of Sum ACE versus the 10-yma J–N values of (a) <ONI>, (b) <AMO>, (c) <AMM>, (d) <GLOTI>, and (e) <QBO>. All scatterplots are inferred to be statistically important, except for the one based on <ONI> (J–N), with the strongest inferred association being the one between Sum ACE and <AMM> (J–N), having $P = 6.8 \times 10^{-5}\%$. The 2010 parametric values should lie in the upper-right quadrant for <AMO>, <AMM>, and <GLOTI>, but in the upper-left quadrant for <ONI> and <QBO>.

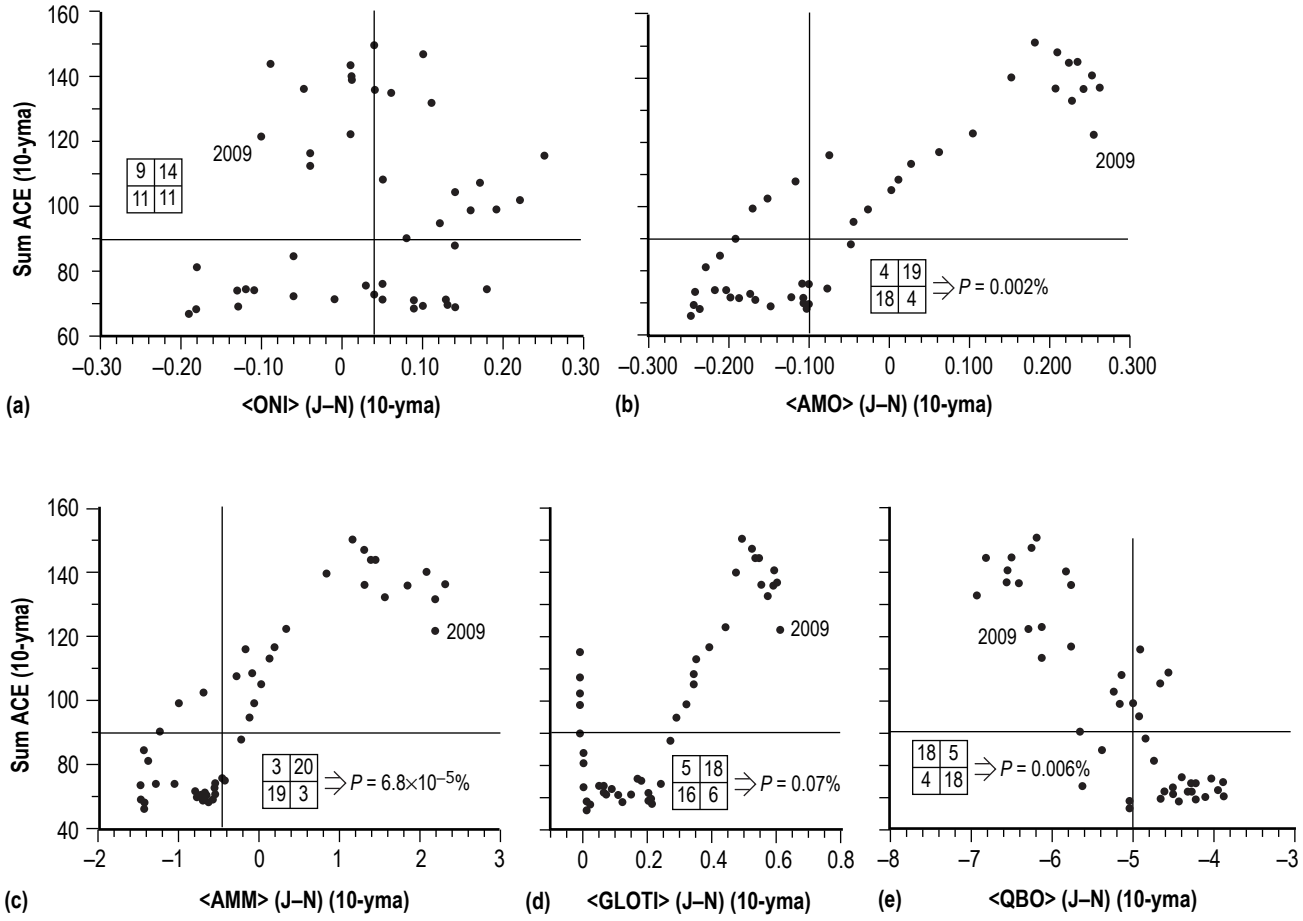


Figure 30. Scatterplots of 10-yma values of Sum ACE versus 10-yma J–N values of (a) <ONI>, (b) <AMO>, (c) <AMM>, (d) <GLOTI>, and (e) <QBO>.

Figure 31 shows the scatterplots of the 10-yma values of Sum NSD versus the 10-yma J–N values of (a) <ONI>, (b) <AMO>, (c) <AMM>, (d) <GLOTI>, and (e) <QBO>. All scatterplots are inferred to be statistically important, except for the one based on <ONI> (J–N), with the strongest inferred association being the one between Sum NSD and <AMM> (J–N), having $P = 1.4\times10^{-6}$ %. The 2010 parametric values should lie in the upper-right quadrant for <AMO>, <AMM>, and <GLOTI>, but in the upper-left quadrant for <ONI> and <QBO>.

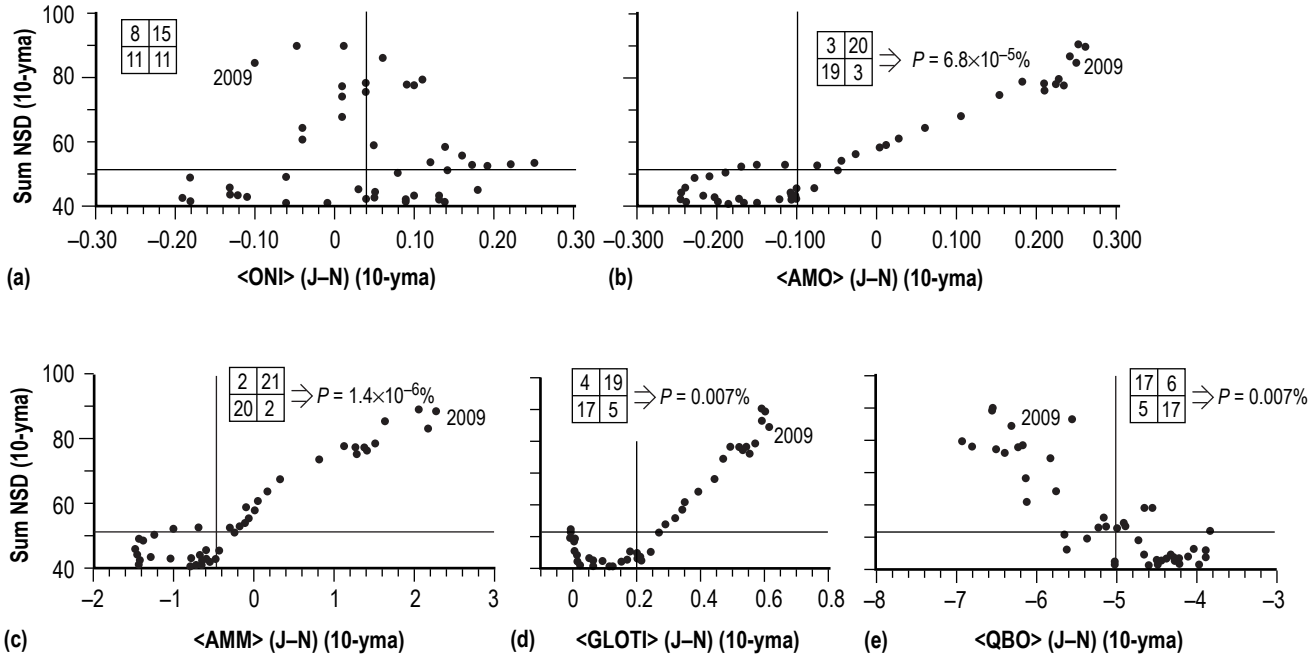


Figure 31. Scatterplots of 10-yma values of Sum NSD versus 10-yma J–N values of (a) <ONI>, (b) <AMO>, (c) <AMM>, (d) <GLOTI>, and (e) <QBO>.

Figure 32 depicts the scatterplots of the 10-yma values of Sum NHD versus the 10-yma J–N values of (a) <ONI>, (b) <AMO>, (c) <AMM>, (d) <GLOTI>, and (e) <QBO>. All scatterplots are inferred to be statistically important, except for the one based on <ONI> (J–N), with the strongest inferred association being the one between Sum NHD and <AMM> (J–N), having $P = 6.8 \times 10^{-5}$ %. The 2010 parametric values should lie in the upper-right quadrant for <AMO>, <AMM>, and <GLOTI>, but in the upper-left quadrant for <ONI> and <QBO>.

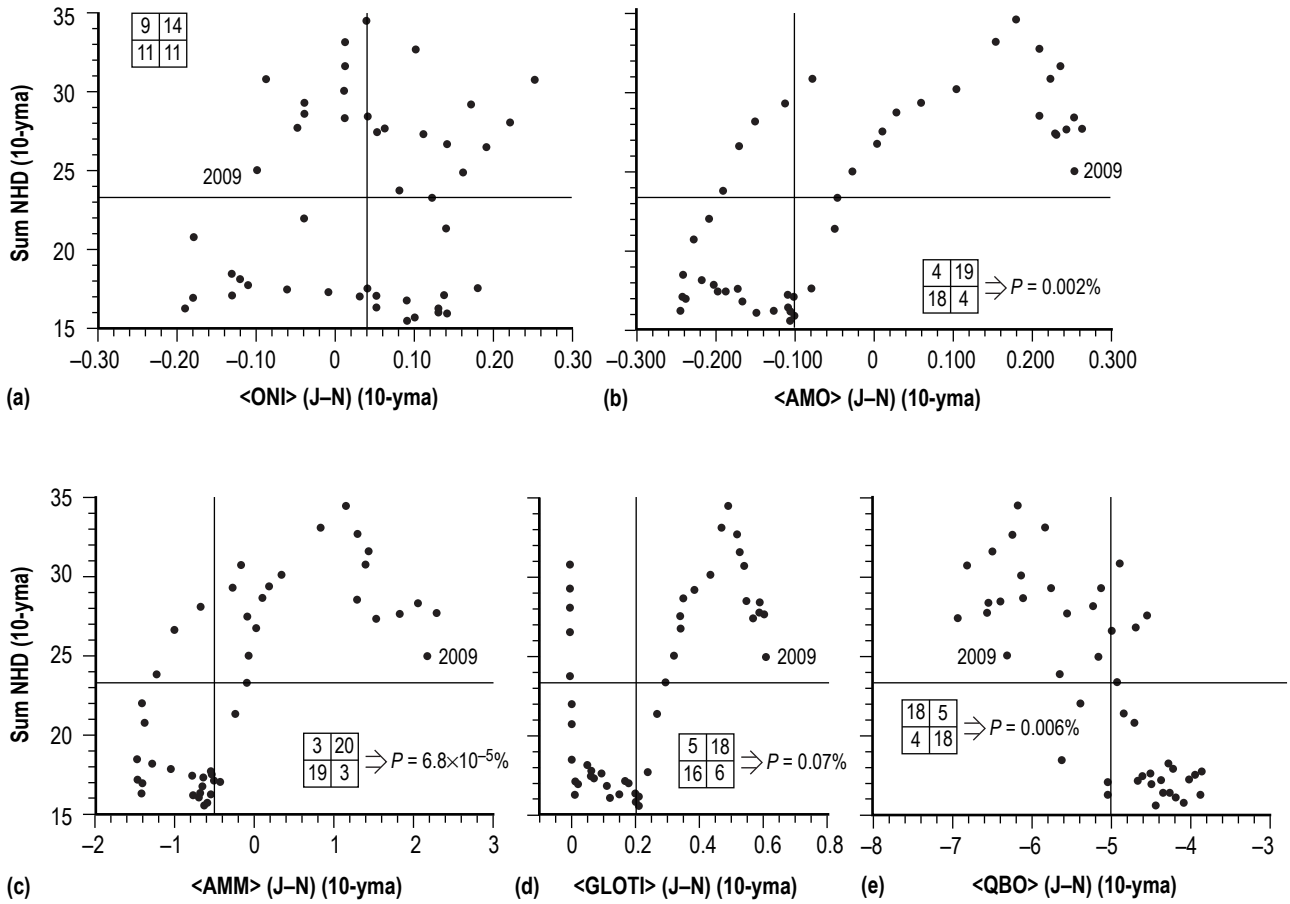


Figure 32. Scatterplots of 10-yma values of Sum NHD versus 10-yma J–N values of (a) <ONI>, (b) <AMO>, (c) <AMM>, (d) <GLOTI>, and (e) <QBO>.

Figure 33 displays the scatterplots of the 10-yma values of Sum NMHD versus the 10-yma J–N values of (a) <ONI>, (b) <AMO>, (c) <AMM>, (d) <GLOTI>, and (e) <QBO>. All scatterplots are inferred to be statistically important, except for the one based on <ONI> (J–N), with the strongest inferred association being the one between Sum NMHD and <AMM> (J–N), having $P = 1.4\times10^{-6}\%$. The 2010 parametric values should lie in the upper-right quadrant for <AMO>, <AMM>, and <GLOTI>, but in the upper-left quadrant for <ONI> and <QBO>.

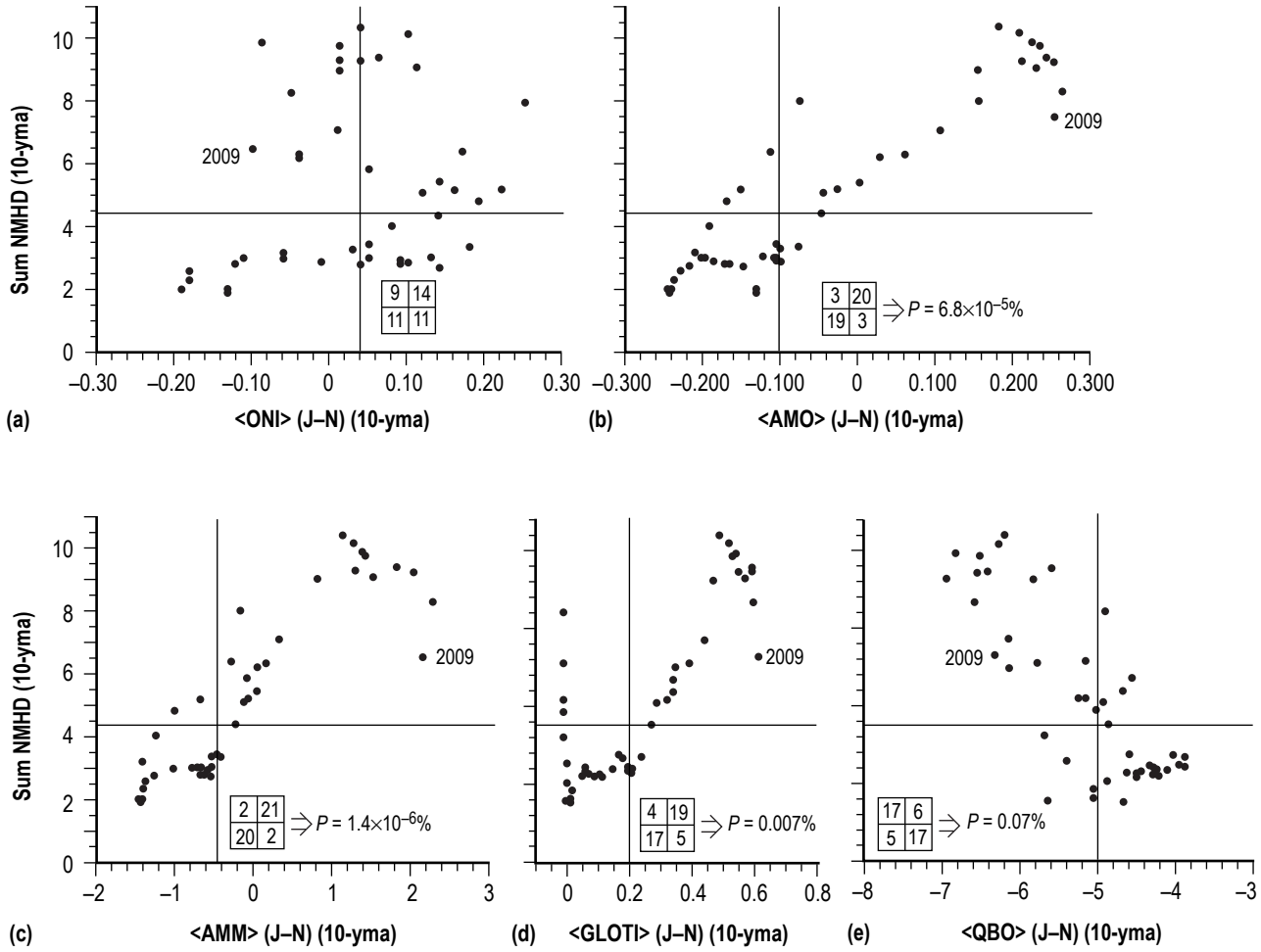


Figure 33. Scatterplots of 10-yma values of Sum NMHD versus 10-yma J–N values of (a) <ONI>, (b) <AMO>, (c) <AMM>, (d) <GLOTI>, and (e) <QBO>.

Figure 34 shows the scatterplots of the 10-yma values of NTCA versus the 10-yma J–N values of (a) <ONI>, (b) <AMO>, (c) <AMM>, (d) <GLOTI>, and (e) <QBO>. All scatterplots are inferred to be statistically important, except for the one based on <ONI> (J–N), with the strongest inferred association being the one between NTCA and <AMM> (J–N), having $P = 1.0 \times 10^{-5}\%$. The 2010 parametric values should lie in the upper-right quadrant for <AMO>, <AMM>, and <GLOTI>, but in the upper-left quadrant for <ONI> and <QBO>.

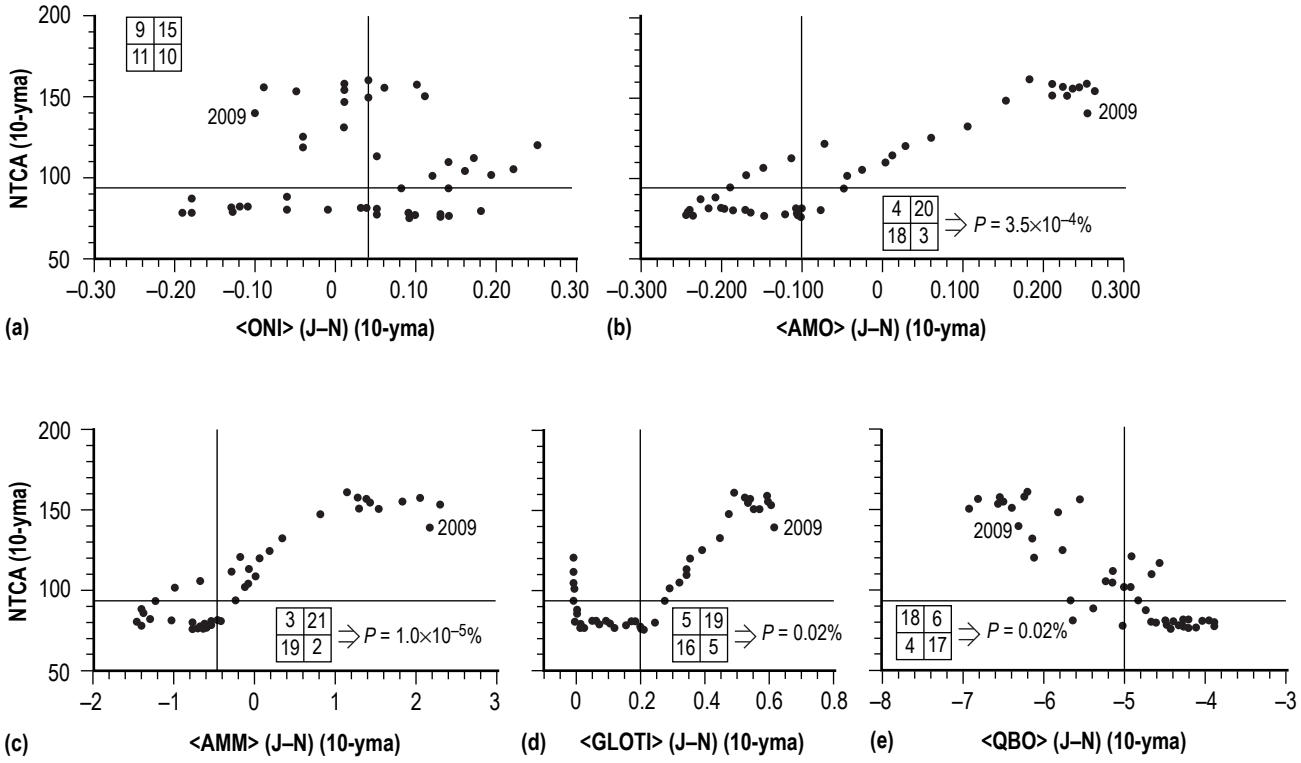


Figure 34. Scatterplots of 10-yma values of NTCA versus 10-yma J–N values of (a) <ONI>, (b) <AMO>, (c) <AMM>, (d) <GLOTI>, and (e) <QBO>.

3. DISCUSSION AND CONCLUSIONS

Prior to the start of the 2015 hurricane season, NOAA[15] predicted that some 6–11 tropical cyclones, 3–6 hurricanes, and 0–2 major hurricanes should be expected to form in the North Atlantic basin, these frequencies being on the low side of the long-term means (11.3, 6.2, and 2.5, respectively). Supporting this prediction was the observation that a strong El Niño was anticipated during the 2015 hurricane season,[16] one expected to be extremely strong and to persist through the 2015–2016 winter. In *The Journal of Alabama Academy of Science* article,[5] Poisson distributions were given presuming positive/negative <ONI> (J–N) values, <AMO> (J–N) values, and combinations of the two. Based strictly on <ONI> (J–N) being positive, it was found that, for tropical cyclones, $P(6–11) = 65.1\%$, $P(<6) = 7.9\%$, and $P(>11) = 27\%$; for hurricanes, $P(3–6) = 60.7\%$, $P(<3) = 9.5\%$, and $P(>6) = 29.8\%$; and, for major hurricanes, $P(0–2) = 75.7\%$ and $P(>2) = 24.3\%$. Incorporating both positive <AMO> (J–N) and <ONI> (J–N) resulted in $P(6–11) = 11.2\%$, $P(<6) = 0.1\%$, and $P(>11) = 88.7\%$ for tropical cyclones; $P(3–6) = 20.1\%$, $P(<3) = 0.6\%$, and $P(>6) = 79.3\%$ for hurricanes; and $P(0–2) = 18.5\%$ and $P(>2) = 81.5\%$ for major hurricanes. In retrospect, the strength of the 2015 El Niño (based on the <ONI> (J–N)) was sufficient to depress the numbers of expected events during the hurricane season, even though the <AMO> (J–N) values were relatively strong.

Table 11 provides a listing of the tropical cyclones that formed during the 2015 hurricane season. Listed are the 11 tropical cyclones by name, their classification (tropical storm (TS), hurricane (H), and major hurricane (MH)), FSD, LSD, PWS, and LP. Four of the tropical cyclones reached hurricane status, with two of them attaining major hurricane status, the most powerful storm being Joaquin, an MH4 tropical cyclone that formed on September 28 and persisted through October 8, having PWS = 115 kt and LP = 931 mb. No tropical cyclone struck the U.S. coastline as a hurricane during the 2015 hurricane season. Other individual storm and seasonal parametric values (e.g., NLAT, WLONG, PDI, ACE, NSD, NHD, etc.) are presently unavailable because the daily 6-hr values of position, wind speed, and pressure have not as yet been posted in the HURDAT2 (they should be available prior to the start of the 2016 hurricane season). For the overall season, <PWS> = 60.9 kt and <LP> = 989.8 mb. The 10-yma trend values for 2010 are computed to be NT = 14.9 (down from 16.1 in 2009), NH = 6.9 (down from 7.6 in 2009), NMH = 2.9 (down from 3.3 in 2009), NUSLFH = 1.0 (down from 1.6 in 2009), <PWS> = 68.6 kt (down from 69.7 in 2009), and <LP> = and 983.3 mb (up from 982.2 in 2009), thus, indicating a continued weakening in the 10-yma trend values. (10-yma trend values of <PWS>, <LP>, <PDI>, and <ACE> have been in decline since 2000; see table 2.)

Table 11. Listing of 2015 tropical cyclones.

Name	Classification	FSD	LSD	PWS	LP
Ana	TS	05/08	05/11	50	998
Bill	TS	06/16	06/18	50	997
Claudette	TS	07/13	07/14	45	1,003
Danny	MH3	08/18	08/24	100	974
Erika	TS	08/25	08/29	45	1,003
Fred	H1	08/30	09/06	75	986
Grace	TS	09/05	09/09	45	1,002
Henri	TS	09/09	09/11	35	1,008
Ida	TS	09/18	09/27	45	1,003
Joaquin	MH4	09/28	10/08	115	931
Kate	H1	11/09	11/12	65	983
mean				60.9	989.8
sd				25.7	22.1

Now, the conventional hurricane season is said to span the interval June 1–November 30 during each year (97% of tropical cyclones and 99% of hurricanes occur within the bounds of the interval June 1–November 30, based on a study[17] of the North Atlantic basin tropical cyclones spanning the interval 1945–2010), having long-term means of DOY 180, DOY 311, and 132 days, respectively, for FSD, LSD, and LOS. During the weather satellite era (1960–2014), the earliest FSD occurred in 2003 (DOY 110, ignoring the statistical outlier event of 1978) and the latest in 1967 and 1977 (DOY 242); the earliest LSD occurred in 1993 (DOY 264) and the latest in 2005 (DOY 371); and the shortest LOS occurred in 1983 (47 days) and the longest in 2003 (235 days). In comparison, the 2015 hurricane season had FSD = DOY 128 (May 8), LSD = DOY 316 (November 12), and LOS = 189 days. Hence, the 2015 hurricane season had an earlier start, a later end, and a longer duration than the respective long-term means. The 10-yma trend values for 2010 are computed to be, respectively, DOY 165, DOY 316, and 153 days. Compared to the 2009 10-yma values (respectively, DOY 168, DOY 321, and 154 days), the 2010 10-yma values for FSD, LSD, and LOS are sooner, sooner, and longer. (Recall from figure 2 that the yearly LOS is inferred to be inversely related to FSD, such that an early FSD suggests a longer LOS and a later FSD suggests a shorter LOS. Based on the occurrence of Ana's FSD (DOY 128), the LOS for the 2015 hurricane season was predicted to be about 187 ± 22 days, which turned out to be an accurate estimate for the 2015 hurricane season.)

The 11 tropical cyclones that formed in the North Atlantic basin during the 2015 hurricane season, although lower than the average number for the post-1994 interval (15), is found to be essentially equal to the long-term mean for the overall interval 1960–2014 (11.3) and within NOAA's prediction interval (6–11) for the 2015 hurricane season. The 4 hurricanes and 2 major hurricanes that formed in the North Atlantic basin during the 2015 hurricane season are found to be slightly fewer in number than the long-term averages for the overall interval 1960–2014 (6.2 and 2.5, respectively), but again within NOAA's prediction interval (3–6 and 0–2, respectively).

Table 12 compares the 2015 ENL hurricane season with the other 14 ENL seasons that have occurred during the weather satellite interval. ENL seasons appear to occur about once every 4 years, on average, having a range of 1–7 years between event occurrences. In terms of the severity of the ENL season, based on the <ONI> (J–N) value, the 2015 ENL has the second highest value (1.63 ºC), second to the 1997 ENL (1.86 ºC) and higher than the 1972 ENL (1.48 ºC). Like the 1997 ENL, the values of <AMO> (J–N) and <QBO> (J–N) were both of positive and the FSD occurred earlier (before June 1). In fact, the FSD for the 2015 ENL season (DOY = 128) is the earliest of all ENL seasons and the LOS for the 2015 ENL season (189 months) is the longest of all ENL seasons. In terms of NTC, the 11 storms of the 2015 ENL is the fourth most of all ENL seasons (fewer than the 18 in 1969, 15 in 2004, and 12 in 2002). Interesting is that all four of these particular ENL seasons had <QBO> (J–N) values that were positive.

Table 12. Tropical cyclone activity during ENL seasons, 1960–2015.

Year	FSD	LSD	LOS	NTC	NH	NMH	NUSLFH	<PWS>	<LP>	<ONI> (J–N)	<AMO> (J–N)	<GLOTI> (J–N)	<QBO> (J–N)
1963	214	302	89	9	7	2	1	81.1	978.1	1.03	–0.071	0.16	–1.80
1965	165	291	127	6	4	1	1	76.7	973.3	1.51	–0.201	–0.09	–17.68
1969	208	328	121	18	12	5	2	80.0	979.6	0.70	–0.055	0.07	9.17
1972	147	309	163	7	3	–	1	64.3	990.9	1.48	–0.340	0.08	–17.92
1977	242	291	50	6	5	1	1	79.2	982.2	0.54	–0.146	0.12	–9.65
1982	154	275	122	6	2	1	–	70.8	983.2	1.31	–0.282	0.07	–0.75
1986	157	325	169	6	4	–	2	67.5	992.8	0.57	–0.265	0.06	–7.47
1987	221	286	66	7	3	1	1	59.3	992.3	1.43	0.177	0.29	–1.93
1991	185	306	122	8	4	2	1	68.1	981.6	0.81	–0.133	0.38	–11.14
1994	183	324	142	7	3	–	–	65.0	989.6	0.58	–0.137	0.32	–18.07
1997	152	290	139	8	3	1	1	55.6	990.8	1.86	0.083	0.50	11.39
2002	196	285	90	12	4	2	1	63.8	985.0	0.94	0.040	0.57	9.16
2004	214	337	124	15	9	6	6	82.8	971.2	0.62	0.256	0.47	8.35
2009	224	314	91	9	3	2	–	65.6	987.2	0.80	0.152	0.64	–11.91
2015	128	316	189	11	4	2	–	60.9	989.8	1.63	0.209	0.87	9.81
mean	186	305	120	9	5	2	1	69.4	984.5	1.05	–0.048	0.30	–3.36
sd	34	19	38	4	3	2	1	8.6	6.8	0.44	0.191	0.27	10.94

Table 13 gives the yearly and mean parametric values for the three groupings of yearly events during the interval 1960–2014, based on determination as given by the value of <ONI> (J–N): ENL, LNL, and neutral seasons. A comparison of the <PWS> and <LP> values for the 2015 ENL season (60.9 kt and 989.8 mb) with the mean for the 14 previous ENL seasons (70.0 kt and 984.1 mb) reveals that the 2015 ENL season was somewhat weaker. Based on its observed <PWS>, the 2015 ENL is the third weakest ENL season and based on <LP>, it is the fifth weakest ENL season. Based on <PWS>, the weakest ENL season is the 1997 ENL season (55.6 kt) and, based on <LP>, the weakest ENL season is the 1986 ENL season (992.8 mb).

The present belief is that the current ongoing ENL will subside and that the 2016 hurricane season will be neutral as determined from the <ONI> (J–N) value. Presuming that the 2016 will indeed be a neutral El Niño Southern Oscillation (ENSO) season, one anticipates that NTC = 12 ± 5, NH = 7 ± 3, NMH = 3 ± 2, and NUSLFH = 2 ± 2, based on the statistical means (and *sd*) given in table 13 for neutral ENSO seasons. <AMO> (J–N) is expected to remain positive in value and <GLOTI> (J–N), of course, will continue to be much warmer than its long-term average. <QBO> (J–N), however, likely will be of negative value.

In conclusion, this study has shown that the FSD of a hurricane season provides a creditable estimate for the LOS, with an early occurrence highly indicative of a longer-than-average LOS and a late occurrence highly indicative of a shorter-than-average LOS. The FSD for the 2015 hurricane season was DOY 128, which suggested an LOS = 187 ± 22 days. The observed LOS for the 2015 hurricane season was LOS = 189 days. For the 2015 hurricane season, NTC = 11, NH = 4, NMH = 2, and NUSLFH = 0, where these values are close to long-term averages (1960–2014), but below the averages associated with the more recent active subinterval 1995–2014. The <PWS> and <LP> for the 2015 hurricane season measured 60.9 kt and 989.8 mb. Based on <ONI> (J–N), the 2015 hurricane season is known to be an ENL season, although one that still is of positive <AMO> (J–N). The occurrence of the strong El Niño during the 2015 ENL season, second in strength only to the 1997 ENL season, had an obvious impact on the numbers and strengths of the NTC during the 2015 hurricane season, even though <AMO> (J–N) continued to be extremely warm (0.209 ºC). Also, like the 1997 ENL season, the 2015 ENL season had positive <QBO> (J–N). Once the HURDAT2 dataset is updated to include the 2015 positions, wind speeds, and pressures, then the other parametric values can be determined. Looking ahead, one anticipates that the current ongoing El Niño will subside prior to the 2016 hurricane season and that, consequently, the next hurricane season likely will be ENSO neutral. Continued positive <AMO> (J–N) is anticipated, as is negative valued <QBO> (J–N) and warmer <GLOTI> (J–N), which together suggests an increase in the NTC, NH, and NMH for the 2016 hurricane season. The unusual occurrence of tropical cyclone Alex on January 13, 2016, is probably indicative that it is best interpreted as being a statistical outlier as what occurred in the 1978 hurricane season, rather than being an indication of a very early start for the 2016 hurricane season.

Table 13. ENL, Neutral, and LNL seasons, based on <ONI> (J–N) values, excluding the 2015 season and <GLOTI> (J–N).

A. ENL (14 seasons)

										Genesis Location		Sum		Sum		Sum		Sum	Sum	NTCA			
Year	FSD	LSD	LOS	NTC	NH	NMH	NUSLFH	<PWS>	<LP>	<NLAT>	<NLONG>	PDI	<PDI>	ACE	<ACE>	NSD	<NSD>	NHD	NMHD	(%)	<ONI>	<AMO>	<QBO>
1963#	214	302	89	9	7	2	1	81.1	978.1	19.7	60.1	95.1	10.6	117.8	13.1	52.00	5.78	37.25	7.00	116.2	1.03	–0.071	–1.80
1965#	165	291	127	6	4	1	1	76.7	973.3	22.8	63.5	72.7	12.1	84.4	14.1	39.50	6.58	27.25	7.50	85.9	1.51	–0.201	–17.68
1969#	208	328	121	18	12	5	2	80.0	979.6	23.9	65.4	132.6	7.4	165.7	9.2	91.25	5.07	40.00	6.50	181.2	0.70	–0.055	9.17
1972#	147	309	163	7	3	–	1	64.3	990.9	32.2	67.5	21.2	3.0	35.7	5.1	30.75	4.39	6.00	–	35.1	1.48	–0.340	–17.92
1977#	242	291	50	6	5	1	1	79.2	982.2	28.1	77.4	20.9	3.5	25.4	4.2	14.75	2.46	6.75	1.00	44.7	0.54	–0.146	–9.65
1982#	154	275	122	6	2	1	–	70.8	983.2	23.8	70.7	23.9	2.7	31.5	5.3	18.50	3.08	5.75	1.25	37.7	1.31	–0.282	–0.75
1986#	157	325	169	6	4	–	2	67.5	992.8	24.3	69.3	24.9	4.2	35.8	6.0	23.25	3.88	10.50	–	36.8	0.57	–0.265	–7.47
1987#	221	286	66	7	3	1	1	59.3	992.3	19.2	56.8	19.0	2.7	34.4	4.9	37.25	5.32	4.00	0.50	44.9	1.43	0.177	–1.93
1991#	185	306	122	8	4	2	1	68.1	981.6	26.6	64.0	25.0	3.1	35.7	4.5	24.25	3.03	8.25	1.25	57.7	0.81	–0.133	–11.14
1994#	183	324	142	7	3	–	–	65.0	989.6	18.3	62.1	19.2	2.7	32.1	4.6	28.75	4.11	7.25	–	35.3	0.58	–0.137	–18.07
1997#	152	290	139	8	3	1	1	55.6	990.8	27.1	69.8	29.1	3.9	40.8	5.1	29.75	3.72	9.50	2.25	53.7	1.86	0.083	11.39
2002#	196	285	90	12	4	2	1	63.8	985.0	26.2	69.9	45.5	3.8	67.0	5.6	57.00	4.75	9.75	3.00	82.6	0.94	0.040	9.16
2004#	214	337	124	15	9	6	6	82.3	971.2	20.0	57.8	217.7	13.8	226.7	15.1	93.00	6.15	45.50	22.25	231.4	0.62	0.256	8.35
2009#	224	314	91	9	3	2	–	65.6	987.2	19.2	51.8	42.6	4.7	52.6	5.8	30.00	3.33	12.00	3.50	68.6	0.80	0.152	–11.91
mean	190	305	115	8.9	4.7	1.7	1.3	70.0	984.1	23.7	64.7	56.4	5.6	70.4	7.3	40.71	4.40	16.41	4.00	79.4	1.01	–0.066	–4.30
sd	31	19	34	3.7	2.8	1.8	1.5	8.6	6.9	4.1	6.7	57.5	3.8	60.2	3.9	24.67	1.26	14.47	5.88	59.5	0.43	0.184	10.71

B. Neutral (28 seasons)

										Genesis Location		Sum		Sum		Sum		Sum	Sum	NTCA			
Year	FSD	LSD	LOS	NTC	NH	NMH	NUSLFH	<PWS>	<LP>	<NLAT>	<NLONG>	PDI	<PDI>	ACE	<ACE>	NSD	<NSD>	NHD	NMHD	(%)	<ONI>	<AMO>	<QBO>
1960	175	263	89	7	4	2	2	82.1	971.7	21.4	71.2	93.5	13.4	88.0	12.6	29.50	4.21	18.25	9.75	92.9	0.12	0.291	–14.16
1961	201	312	112	11	8	7	1	97.7	957.0	19.5	61.5	201.8	18.3	205.5	18.7	70.75	6.43	47.50	24.50	230.4	–0.04	0.036	7.10
1962	239	295	57	5	3	1	–	75.0	974.8	22.7	57.4	25.2	5.0	35.5	7.1	22.25	4.45	10.75	0.50	40.9	–0.18	0.006	–14.64
1966	157	315	159	11	7	3	2	74.1	983.6	20.9	57.4	113.2	11.4	145.1	13.2	64.00	5.82	42.00	8.50	139.2	0.07	–0.011	8.75
1967	242	304	63	8	6	1	1	79.4	975.8	20.1	56.3	101.5	12.7	121.9	15.2	58.00	7.25	36.25	5.50	100.8	–0.14	–0.170	–4.99
1968	154	295	142	8	5	–	1	63.8	986.1	27.1	72.9	26.9	3.4	45.2	5.7	33.75	4.22	11.75	–	47.5	0.48	–0.168	–17.87
1976	144	302	159	10	6	2	1	70.0	981.8	25.0	65.2	62.0	6.2	84.0	8.4	49.75	4.98	25.25	1.00	86.2	0.43	–0.300	–4.55
1978*	212	305	94	11	5	2	–	68.6	986.5	23.5	66.1	46.6	4.2	61.5	5.6	40.50	3.68	13.50	3.50	82.3	–0.29	–0.211	6.07
1979	173	298	126	9	6	2	3	76.1	977.4	20.5	63.2	85.3	9.5	92.9	10.3	45.75	5.08	21.75	5.75	103.8	0.25	–0.074	–21.89
1980	215	332	118	11	9	2	1	83.2	976.1	23.8	54.1	141.6	12.9	149.3	13.6	62.25	5.66	38.25	7.25	130.3	0.10	0.002	10.60
1981	127	321	195	12	7	3	–	75.0	981.8	23.2	61.3	72.8	6.1	100.4	8.4	66.00	5.50	22.50	3.75	112.6	–0.28	–0.084	–7.45
1983	227	273	47	4	3	1	1	72.5	985.5	28.6	75.9	10.8	2.7	17.4	4.4	13.75	3.44	3.50	0.25	30.5	–0.28	–0.112	–5.83
1984	232	359	128	13	5	1	1	61.9	989.2	25.3	63.0	54.2	4.2	84.4	6.5	63.25	4.87	18.25	0.75	80.3	–0.46	–0.277	–21.91
1985	197	327	131	11	7	3	6	78.2	977.4	25.2	71.6	67.5	6.1	88.0	8.0	51.25	4.66	21.25	4.00	105.8	–0.49	–0.189	11.87
1989	177	338	162	11	7	2	3	78.6	976.5	18.1	56.8	119.9	10.9	135.0	12.3	65.75	5.98	31.75	9.75	129.8	–0.30	0.021	–16.56
1990	205	293	89	14	8	1	–	65.4	987.1	19.6	52.1	62.6	4.5	96.8	6.9	72.50	5.18	26.75	1.00	100.3	0.31	0.049	12.54
1992	113	301	189	7	4	1	1	81.4	974.4	27.5	58.6	65.4	9.3	76.2	10.9	40.25	5.75	15.75	3.50	66.7	0.05	–0.275	–3.43

Table 13. ENL, Neutral, and LNL seasons, based on <ONI> (J–N) values, excluding the 2015 season and <GLOTI> (J–N) (Continued).

B. Neutral (28 seasons) (Continued)

										Genesis Location		Sum		Sum		Sum		Sum	Sum	NTCA			
Year	FSD	LSD	LOS	NTC	NH	NMH	NUSLFH	<PWS>	<LP>	<NLAT>	<NLONG>	PDI	<PDI>	ACE	ACE	NSD	<NSD>	NHD	NMHD	(%)	<ONI>	<AMO>	<QBO>
1993	170	264	95	8	4	1	1	60.6	989.9	20.4	63.1	25.6	3.2	38.4	4.8	29.25	3.66	9.75	0.75	51.5	0.24	–0.218	–0.87
1995	154	305	152	19	11	5	2	76.3	974.4	18.8	61.7	181.2	9.5	227.2	12.0	121.25	6.38	61.25	11.50	221.4	–0.48	0.207	7.76
1996	171	331	161	13	9	6	2	80.0	972.8	16.2	62.2	142.6	11.0	166.2	12.8	79.00	6.08	45.00	13.00	192.2	–0.29	–0.076	–22.39
2001	156	337	182	15	9	4	–	75.7	979.3	22.4	63.8	80.4	5.4	109.0	7.3	68.25	4.55	25.50	4.25	135.1	–0.08	0.219	–16.40
2003	110	344	235	16	7	3	2	70.6	981.8	22.0	64.7	165.1	10.3	176.4	11.0	92.50	5.78	32.50	16.75	178.6	0.30	0.351	–21.01
2005	160	371	212	28	15	7	6	76.8	974.4	22.5	66.0	221.1	7.9	250.1	8.9	131.25	4.69	49.50	17.50	278.3	–0.02	0.353	–26.13
2006	162	275	114	10	5	2	–	68.5	984.7	21.9	56.6	55.1	5.5	78.5	7.9	63.75	6.38	21.25	2.00	88.7	0.47	0.368	10.41
2008	152	314	163	16	8	5	3	77.2	977.3	19.7	63.7	112.0	7.0	146.1	9.1	89.75	5.61	29.75	7.50	162.3	–0.30	0.176	11.69
2012	140	303	164	19	10	2	1	66.6	981.8	21.9	58.4	85.9	4.5	136.3	7.2	102.75	5.41	24.50	0.25	120.9	0.30	0.361	–25.28
2013	156	341	186	14	2	–	–	53.2	996.6	21.5	58.7	18.7	1.3	37.2	2.7	42.25	3.13	3.25	–	46.5	–0.28	0.213	13.26
2014	182	300	119	8	6	2	1	76.3	977.3	19.4	67.2	58.2	7.3	73.0	9.1	37.75	4.72	19.50	3.75	83.9	0.25	0.234	–20.94
mean	175	311	137	11.8	6.6	2.5	1.5	73.7	979.8	22.1	62.5	89.2	7.6	109.5	9.3	60.96	5.13	25.96	5.95	115.7	–0.02	0.026	–5.94
sd	36	27	47	4.9	2.8	1.9	1.6	8.6	7.5	2.9	5.8	55.5	4.0	58.7	3.6	28.21	1.00	14.20	6.17	60.6	0.30	0.216	13.82

C. LNL (13 seasons)

										Genesis Location		Sum		Sum		Sum		Sum	Sum	NTCA			
Year	FSD	LSD	LOS	NTC	NH	NMH	NUSLFH	<PWS>	<LP>	<NLAT>	<NLONG>	PDI	<PDI>	ACE	<ACE>	NSD	<NSD>	NHD	NMHD	(%)	<ONI>	<AMO>	<QBO>
1964[&]	159	313	155	12	6	6	4	82.1	968.2	21.9	62.7	156.2	13.0	170.0	14.2	71.25	5.94	43.00	14.75	183.9	–0.73	–0.161	0.26
1970[&]	140	301	162	10	5	2	1	72.5	986.0	24.4	74.0	26.5	2.7	40.0	4.0	30.25	3.03	6.75	1.00	64.2	–0.60	–0.172	–20.42
1971[&]	186	325	140	13	6	1	3	70.4	984.6	25.1	69.3	66.6	5.1	96.8	7.4	61.75	4.75	28.75	1.00	97.9	–0.77	–0.320	8.57
1973[&]	184	300	117	8	4	1	–	68.8	984.3	22.8	63.8	29.4	3.7	47.9	6.0	38.75	4.84	10.50	0.25	53.6	–1.30	–0.149	6.18
1974[&]	176	281	106	11	4	2	1	67.7	990.2	24.7	69.5	54.2	4.9	68.2	6.2	42.25	3.84	14.25	4.25	83.1	–0.59	–0.465	–20.95
1975[&]	180	346	167	9	6	3	1	83.9	971.9	27.7	61.8	56.4	6.3	76.1	8.5	46.50	5.17	20.25	2.25	91.4	–1.31	–0.284	8.85
1988[&]	220	329	110	12	5	3	1	72.9	976.2	21.6	64.6	93.9	7.8	103.1	8.6	46.75	3.90	21.25	9.00	117.0	–1.39	–0.005	–1.80
1998[&]	210	335	126	14	10	3	3	83.2	972.7	19.2	57.5	157.9	11.3	181.7	13.0	87.75	6.27	48.50	9.25	167.9	–0.93	0.450	–19.89
1999[&]	163	325	163	12	8	5	3	91.3	964.6	17.5	64.1	159.2	13.3	176.4	14.7	78.50	6.54	40.25	14.00	180.4	–1.15	0.157	11.51
2000[&]	217	303	87	15	8	3	–	70.0	981.7	21.0	62.3	89.2	5.9	119.2	7.9	71.25	4.75	32.75	5.00	133.5	–0.63	0.045	–13.48
2007[&]	129	346	218	15	6	2	1	65.0	986.1	21.9	65.1	73.1	4.9	73.8	4.9	38.25	2.55	12.25	6.00	98.8	–0.73	0.136	–26.41
2010[&]	177	311	135	19	12	5	–	78.7	975.3	16.6	58.8	139.5	7.3	166.5	8.8	191.25	10.07	38.50	11.00	230.9	–1.15	0.425	–0.65
2011[&]	179	315	137	19	7	4	1	66.3	984.2	22.0	65.2	88.6	4.7	126.1	6.6	90.00	4.74	26.00	4.50	145.0	–0.54	0.112	–1.77
mean	178	318	140	13	6.7	3.1	1.5	74.8	978.9	22.0	64.5	91.6	7.0	111.2	8.5	68.81	5.11	26.38	6.33	126.7	–0.91	–0.018	–5.38
sd	27	19	34	3.4	2.3	1.6	1.3	8.2	7.9	3.1	4.4	47.6	3.5	49.9	3.4	41.80	1.90	13.54	4.89	52.6	0.31	0.276	13.18

* = ST1, an SS/TS that originated 01/19/1978 and ended on 01/22/1978 having PWS = 40 kt, LP =1,002, NSD = 3 days, and a genesis location of 23.5° N., 64.6° W., is considered a statistical outlier; consequently, it is ignored in this analysis.

[#] = ENL season; i.e., <ONI> (J–N) = 0.5 or more positive in value.

[&] = LNL season; i.e., <ONI> (J–N) = –0.5 or more negative in value.

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14. ABSTRACT

This Technical Publication represents an extension of previous work concerning tropical cyclone activity in the North Atlantic basin during the weather satellite era (1960–2014). In particular, it extends the study originally published in *The Journal of the Alabama Academy of Science* (Vol. 86, No. 1, pp. 29–61, January 2015), providing yearly and 10-year moving averages (10-yma) for a number of important tropical cyclone and climate parameters, including (1) first storm day, (2) last storm day, (3) length of season, (4) frequencies, (5) peak wind speed, (6) lowest pressure, (7) position location at formation, (8) power dissipation and accumulated cyclone energy indices, (9) numbers of storm days, hurricane days, and major hurricane days, (10) net tropical cyclone activity index, and the (11) December–May and June–November means of the oceanic Niño index, Atlantic multidecadal oscillation index, Atlantic meridional mode index, global land-ocean temperature index, and quasi-biennial oscillation index. Additionally, scatterplots of the tropical cyclone and climate parametric values using 10-yma averages are examined and the 2015 North Atlantic basin tropical cyclone season is briefly discussed.

15. SUBJECT TERMS

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